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Building The Right Image

Several of the articles in this issue of *Review* contribute toward a composite image of the world of a pioneering scientist. It is a world that few non-scientists understand, although they often readily assign to it an aura of glamour and excitement. They overlook, however, the interminable hours of dull routine, the roadblocks, the frustrations, and the hypotheses that so often lose their brilliance with the mere tilting of a test tube or adjusting of a slide rule.

Misconceptions about basic research take other forms, the most damaging ones of which are concerned with just plain ignorance about the ways of science. Scientists will undoubtedly continue to be targets of ridicule for the very things that keep their disciplines alive.

President John F. Kennedy placed at least a part of the responsibility of achieving a wider understanding of basic research on the scientific community itself. Speaking at the 100th Anniversary Convocation of the National Academy of Sciences—just a month before his death—he said:

"If basic research is to be properly regarded, it must be better understood. I ask you to reflect on this problem and on the means by which, in years to come, our society can assure continuing backing to fundamental research in the life sciences, the physical sciences, the social sciences, our natural resources, on agriculture, our protection against pollution and erosion. Together, the scientific community, the government, industry, and education must work out the way to nourish American science in all its power and vitality."

One might well speculate about the welfare of mankind in generations to come if pioneering research in the agricultural sciences is privileged to continue contributing to this vitality.

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Pioneering Research in the USDA

On the 17th of May, 1957, Dr. Byron T. Shaw, Administrator of the Department's Agricultural Research Service, signed a memorandum that set the stage for the realization of a new concept in agricultural science—the pioneering research laboratory.

The memorandum stated, in part, that a need existed "for the freer play of genius in agricultural research and that means should be thought through to permit and encourage it. . . . Pioneering research will be undertaken to discover the principles underlying research areas and to develop theory which will greatly facilitate problem research as needs arise. It will be expected to build a foundation for the quick, effective, and economic solution of research problems and provide means for the recognition of research scientists and for their research achievement and potential."

Basically, of course, pioneering research per se did not represent an entirely new concept—even for the Department of Agriculture. But the recognition and emphasis given by establishing pioneering research *laboratories* was clearly a new exploration aimed at unknown frontiers.

The need for this recognition and emphasis was aptly explained in 1958 by Dr. T. C. Byerly, who at that time was Deputy Administrator of ARS.

"We have had great success in solving agricultural problems as they have been recognized—by application of established principles and theory, through basic research necessary to the solution of those problems, and, more often, by the hoary process of cut and try. So successful have we been that we have developed a beautiful veneer of superficial technological information concealing an infinite ingnorance of the underlying processes and causes." [1]

Three examples have been cited to illustrate the thinness of this veneer: The apparent successes and ultimate partial failure of a multitude of chemical insecticides, the identification of successive disease-resistant cereals, and the unique condition brought on by an efficiency-increasing technology to the immediate advantage of the individual but without regard to the aggregate adjustments ultimately required. In each of these areas, the Department has set up pioneering research programs.

[1] Address by T. C. Byerly at the annual meeting of the American Association of Land-Grant Colleges and State Universities, Washington, D.C., November 11, 1958.

Shortly after the pioneering laboratories were established, the Agricultural Research Institute of the National Academy of Sciences adopted a resolution commending the U.S. Department of Agriculture for its action. Speaking at the 1958 annual meeting of the Institute, Dr. Shaw noted that the resolution was a "highly gratifying experience" for the Department.

"It was a great satisfaction to have our action labeled as the single most significant step in decades to promote the welfare of the fundamental elements of agricultural science. More importantly, it was gratifying to earn this approval from an organization of such unquestioned prestige and influence as the Agricultural Research Institute.

"We look on these pioneering laboratories as a new device for doing basic research. As you know, basic research is the starting point for the imaginative processes that lead to new things, and new ways of doing things." [2]

Dr. Shaw recognized the growing interest of the land-grant colleges and universities in basic research. "They have long been centers of basic research, and we hope they will continue to be and to expand. We hope so, not only for their direct contributions to our store of knowledge, but also because it is through such research that many of our best scientists are trained."

Under Dr. Shaw's formal directive establishing the pioneering research program (July 16, 1959), laboratory staffs carry broad responsibilities and enjoy unique privileges. The laboratories themselves offer the opportunity to work in an environment suited to progress in science. Staffs must be able and willing to do productive, undirected research beyond the frontiers of present knowledge. As with all basic research, the individual scientist must formulate questions based on observations or intuition, assemble the relevant information, develop hypotheses, and test them with adequate data. The program may be only indirectly related to problem areas in agriculture. Leaders have no administrative burdens; individual achievement does not go unrecognized.

Establishment of the pioneering laboratories did not imply that basic research would be curtailed or deemphasized among the Department's research divisions. Actually, each division is encouraged, wherever possible, to expand its basic studies. During the past 15 years, the Department has increased the proportion of basic to total research from 7 to 29.9 percent. In the Agricultural Research Service, about 35.9 percent of the research is now in the basic category. Today, the Department of Agriculture considers basic research a full partner of applied research, although there have been times in the past when its function was largely to supplement applied research. Eventually, the Department hopes to attain a 50–50 ratio of basic to applied research. The pioneering laboratories—now nearly seven years old—represent one step toward this goal.

Procedures for staffing the pioneering research laboratories were clearly delineated and agreed upon before any area of activity was specified. The scientists were required to have demonstrated their capacity to work productively and progressively in an atmosphere where exploration into the unknown, without specific objectives, is a continuous undertaking. At the same time, the door was left open for the selection of younger scientists with evidence of genius and years of potential basic research productivity. Significantly, several of the laboratory leaders are young men at the threshold of their careers. Moreover, the associated personnel in many laboratories includes promising junior scientists.

The importance of the pioneering laboratory concept, to junior scientists in particular, has been further emphasized by the establishment in 1960 of a formal postdoctoral research associateship program. This program provides for not more than 25 professional research associateship positions at GS–11 and above in the pioneering research laboratories. These associateships have been announced by the National Academy of Sciences-National Research Council, which is also the agency that screens applications and makes recommendations on appointments to the Department.

Most of the laboratories are physically small, consisting of a single scientist or group of scientists with common interests and a demonstrated research capacity for self-direction in new, unknown areas. Each laboratory was established through the approval of a charter that states the area within which research will be conducted.

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[2] Address by Byron T. Shaw at the annual meeting, Agricultural Research Institute, National Academy of Sciences, Washington, D.C., October 14, 1958.

Sixteen of the laboratories are in the Agricultural Research Service, four in Forest Service, and one each in Agricultural Marketing Service and Economic Research Service. Following is a description of the research activity in each.

AGRICULTURAL RESEARCH SERVICE

Agricultural Engineering Research Division

PHYSICS OF FINE PARTICLES—The long-term research program at this laboratory deals with the physical behavior and properties of fine, solid particles, liquid droplets and particulate systems, and closely related topics. Presently emphasized are studies of aerosol mechanics, that is, the fluid-mechanical treatment of fine particle suspensions, particle statistics, and characterization of aerosol deposits. In aerosol mechanics, the theoretical structures under consideration are based on the mathematical theory of stochastic processes. A similar theoretical basis is motivating experiments on fluorescent tracing of aerosol deposits on solid surfaces.

Cooperative studies are being conducted with the USDA Soft Wheat Quality Laboratory on heat and moisture diffusion through fine-grained starch systems.

The fundamental research program at this laboratory reflects the critical need to gain more knowledge about pesticide application, air pollution, and product processing. Recent progress publications cite accomplishments concerning theoretical treatment of soil fumigant diffusion; droplet impaction processes and the significance of certain impaction measurement techniques; a possible structure for Brownian motion theory for a particle-size-distributed system; and stochastic differential equations.

The laboratory was established January 11, 1962 [3] and is located at Wooster, Ohio. Ross D. Brazee is Leader.

Animal Husbandry Research Division

BLOOD ANTIGEN—Using the tools of immunogenetics and immunochemistry, this laboratory is investigating three major problem areas of biology. The first deals with the study of somatic variation and somatic mutation. The model system being used is the differences in the red cell antigens of humans and of pigeons as detected with an antibody-like material found in the seed extracts of *Phaseolus lunatus* (a lectin). The variant cells are antigen-lacking cells, and their number is determined by an isotope dilution procedure.

Lectins are also being used in studying development and differentiation. Here, the model system is one in which an agglutinogen of chickens is under the control of the genotype and the hormonal environment.

Lectins themselves are being studied as models for antibody structure and specificity.

Research in this laboratory has resulted in the development of a method for obtaining stroma that is more efficient than conventional ones. It will be useful in studying the antigenic property of cells and the properties of agglutinins.

The laboratory was established September 3, 1957 and is located at Beltsville, Maryland. Sam L. Scheinberg is Leader.

[3] Dates given under each laboratory heading refer to the dates when charters were approved.

BASIC ANIMAL GENETICS—Primary research emphasis at this laboratory is directed toward an increased understanding of the complex systems that affect and determine quantitative traits of animals. These traits have a continuous distribution, are determined by many genes, and are affected by environment. For each trait, millions of unique gene combinations or genotypes are possible; the effects of individual genes can seldom be identified. Therefore, statistical methods must be used to ascertain gene action, estimate parameters, and compare theoretical and experimental results.

The laboratory was established July 8, 1958 and is located at Lafayette, Ind. Wendell H. Kyle is Leader.

This issue of Review also carries a separate article describing the detailed research program at the Animal Genetics Pioneering Research Laboratory. *See page 21.*

Crops Research Division

PLANT HORMONES AND REGULATORS—The long-term objective of this research is to arrive at a progressively clearer understanding of how plant hormones and regulating chemicals control the growth and behavior of plants. The experimental approach is conducted in two phases: (1) the isolation and application of naturally-occuring plant hormones and the application of other regulating compounds, and (2) the detection and study of cellular and morphological responses to these substances. Other areas under study are: Mechanism of phloem transport, enzyme production, altered enzyme activity, and the chemical nature of the first response evidenced in the nucleus or other cell parts after application of hormones and regulators.

A new method developed for locating the distribution of virus antigen in plant tissue is being used to gain an understanding of the mechanism of phloem transport. In this research, virus particles are used as models to learn how molecules are translocated in the phloem. The effect of chemicals on the initiation and development of flowers and on vegetative bud growth is also being investigated. Research aimed at discovering the primary chemical response of growth accelerators such as indoleacetic acid has been initiated.

The laboratory was established December 27, 1962 and is located at Beltsville, Maryland. John W. Mitchell is leader.

PLANT PHYSIOLOGY—This laboratory is studying the regulatory effects of light and light interacting with other environmental conditions on photomorphogenesis and related phenomena. Early physiological studies showed that photoperiodic responses, seed germination, stem lengthening, and formation of certain plant pigments were under the control of a single photoreaction. This reaction was photoreversible, with maxima for action in opposite directions at about 660 and 730 mu, respectively. Photoreception is by a single pigment that exists in either of two forms that are interconvertible by radiation. One form has an absorption maximum near 660 and the other near 730 mu. The 730-absorbing form is believed to be biologically active and the 660 form inactive. The 730 form is known to be unstable; in darkness it reverts in time to the 660 form.

The pigment was physically detected *in vivo* by optical-difference measurements made with a spectrophotometer of special construction and sensitivity. The method of assay was dictated by the photoreversible properties of the pigment as revealed by physiological studies. The method involved measurement of the difference in optical density at 660 and 730 mu, with the pigment first completely in one form and then completely in the other. The difference between these two differences was a measure of the reversibility of the system.

The presence of phytochrome has been detected *in vivo* in many species of plants by this physical method. The method has also proved effective as an assay in the extraction and purification of phytochrome. Procedures have now been perfected for the isolation of the pigment at levels of purity and concentration adequate for study of its molecular properties.

The laboratory was established October 23, 1957 and is located at Beltsville, Maryland. Harry A. Borthwick is Leader.

PLANT VIROLOGY—Research at this laboratory deals with the physiology and biochemistry of plant viruses with emphasis on infection processes. The basic objective is to determine what happens after a virus particle enters a plant, how it multi-

plies, the response of the host plant to this invasion, and how plant viruses are related.

A procedure has been developed for the isolation of infectious RNA from tobacco tissues infected with tobacco mosaic virus. This procedure involves conditions which will not release infectious RNA from complete virus and has led to the conclusion that a form exists within the infected cell which, if not being free RNA, at least is present in some form other than completed virus particles.

New procedures have been developed for the purification of tobacco mosaic virus, cucumber mosaic virus, and pod mottle virus. Various specific buffering conditions are required to keep some viruses adequately suspended. For some a high ionic strength is necessary; for others a very low ionic strength is important. The hydrogen ion concentration is also critical in some instances. Occasionally a specific salt is necessary to prevent aggregation or to prevent dissociation of the virus particles; whereas with other viruses certain ions will induce aggregation and precipitation.

Work is continuing on the detection and identification of extremely small quantities of viruses which will be important in eliminating virus sources in vegetatively propagated plants. Particular attention will be given to (a) leafhopper transmitted viruses, notably with aster yellows, which reproduces within the insect vector as well as in plant hosts, and (b) other viruses which for one reason or another have been difficult to purify and are unique in some aspect of symptomatology, morphology, or some other characteristic that would lead one to believe there will be a marked difference between the infectious agent and that of viruses previously purified.

The laboratory was established September 22, 1958 and is located at Beltsville, Maryland. Russell L. Steere is Leader.

Entomology Research Division

INSECT PATHOLOGY—Pathogenic bacteria for insects are intensively studied at this laboratory to determine their mode of action and to attempt to standardize commercial preparations for insect control. Among the bacteria currently under investigation are the Japanese beetle milky disease organisms, *Bacillus popilliae* Dutky and *Bacillus lentimorbus* Dutky, and some 28 strains, varieties and species of the crystalliferous pathogens related to *Bacillus thuringiensis* Berliner. A number of clostridial types of bacteria have been recently isolated from insects. These organisms have not been previously encountered in insects. Because of their extremely fastidious growth characteristics, studies to aid in propagating these pathogens are being carried out. Stock cultures of many bacterial pathogens of insects from all over the world are maintained here for study.

Viruses affecting insects are collected and studied to determine their mode of invasion and development in the insect host. Methods of measuring the level of virulence and the rate of variation within viral populations are being developed. Studies of tumorous or aberrant growth in insects infected with granulosis virus are under way. Electron-microscope studies are complementary to this work. A great deal of emphasis is also being placed on nematode-associated and rickettsial pathogens of insects.

In cooperation with the U.S. Naval Missile Center, research is being conducted to determine the effects of high altitude radiation—particularly heavy cosmic primaries—on the gain and loss of pathogenicity and other changes in biochemistry of the insect pathogens *Bacillus popilliae* and *Bacillus thuringiensis.*

The laboratory was established February 3, 1958 and is located at Beltsville, Maryland. A. H. Heimpel is Leader.

INSECT PHYSIOLOGY—Research on the function and metabolic fate of sterols, which in insects serve as essential nutrients for the support of growth and metamorphosis, includes studies concerned with the uptake and utilization of sterols from the diet, the metabolic conversions that these sterols undergo in the insect during their utilization, investigation as to the structure of the sterols in various insect species and various developmental stages of these species, sterol storage and the transfer of the sterols from one developmental stage to another, and the role or physiological functions of sterols in adult insects.

Hydrocarbons are components of the cuticular waxes of many species of insects and as such are important in water balance and are involved in insecticide penetration. Studies are being conducted on the chemical structure of insect hydrocarbons

and on their *in vivo* and *in vitro* biosynthesis and transport in living systems.

Studies on insect photoperiod include the following: The effect of photoperiod on insect growth and development and on diapause; wave length vs. biological activity (action spectra); and biochemical and physiological changes brought about by photoperiod in relation to the endocrine-regulated processes of insects. The vision studies include investigations on the role of carotene in insect vision and the effect of vitamin A deficiency on vision and photoresponse in the house fly and on the structure of the compound eye.

Other research activity is concerned with physiological and biochemical studies on insect hormones and on insect attractants and plant feeding stimulants.

The laboratory was established February 3, 1958 and is located at Beltsville, Maryland. W. E. Robbins is Leader.

Human Nutrition Research Division

CELLULAR METABOLISM—The function and growth of all living organisms depend upon transformations of a limited assortment of low-molecular compounds. Thus microorganisms can serve as efficient tools for exploring many problems of metabolism at the cellular or sub-cellular level. Information thus developed may, as it often has in the past, provide new insight into the role and function of nutrients in the metabolism of higher animals.

The current program of this laboratory includes investigations in two areas: (1) Interrelationships in the metabolism of amino acids and in the mechanism of serine biosynthesis, and (2) carbohydrate-nitrogen relationships in growth and protein synthesis.

Studies with the lactic acid bacterium, *Leuconostoc mesenteroides* as a tool have shown that efficient utilization of amino acids depends in part upon the relative concentration of one amino acid with respect to another in the diet provided by the basal medium. Imbalances in five different pairs of amino acids caused significant inhibition of growth by this organism. Studies of amino acid interactions have proceeded to a consideration of factors affecting the growth of the test organisms in the absence of serine—one of the amino acids

that is nonessential in mammalian nutrition and must, therefore, be synthesized from other dietary constituents.

Students of animal nutrition have observed that rats and chicks grow better and make more efficient use of dietary nitrogen if carbohydrate is supplied as a polysaccharide rather than as a disaccharide or simple sugar. Under some conditions, the ciliated protozoan, *Tetrahymena pyriformis,* behaves similarly. It has been used, therefore, as a tool to investigate this phenomenon which has not had a completely satisfactory explanation in terms of mammalian nutrition. With the proper relationships between carbohydrate and nitrogen in the medium, *T. pyriformis* converts media nitrogen to protein nitrogen more efficiently in the presence of dextrin than it does with glucose.

The laboratory was established January 27, 1958

and is located at Beltsville, Maryland. Howard Reynolds is Leader.

Soil and Water Conservation Research Division

MINERAL NUTRITION OF PLANTS—Research in this laboratory is directed to studies of the processes related to mineral nutrition of plants, particularly as to the way nutrient elements enter into roots—a phenomenon basic to all life.

Phosphate entry into the root was found to be coupled to oxidative phosphorylation with formation of adenosine triphosphate associated with oxidation through the respiratory chain. In particular, it takes place upon the oxidation-reduction change of cytochrome b coupled with dehydrogenation of succinic acid and diphosphopyridine nucleotide. This coupling of phosphate entry to use of oxygen is one of the reasons for requirement of aerobic conditions in nutrient uptake. Yeast, by contrast and for comparative information, is found to take up phosphate anaerobically by the splitting of glucose.

Many plants growing on calcareous soil developed typical chlorosis because of inadequate nutrition with respect to iron. It has been established that the passage of iron into the root depends on reduction at the surface and complexing (chelating) with citric, malic, and other acids within the plant. The low solubility of iron in calcareous soils is enhanced by chelating compounds and these can be used to measure the level of iron supply. Plant varieties differ widely in the level of iron supply required for active growth. Utilization of iron in the plant interacts strongly with copper, zinc, and phosphate.

The Mineral Nutrition Laboratory is the "pioneer" among the pioneering research groups, being established August 21, 1957. It is under the direction of Chief Scientist Sterling B. Hendricks, recipient of numerous awards including the President's Distinguished Service Award in 1958. The laboratory is located at Beltsville, Maryland.

Utilization Research & Development Divisions

CHEMISTRY OF ANIMAL PROTEINS—One of the major scientific problems in biology and agriculture is to correlate biological function with the molecular structures of cellular constituents, particularly the proteins.

This laboratory has undertaken basic research on the relation of the structures of the milk proteins to their properties. The program involves three major areas of research: (1) purification of proteins, (2) amino acid analysis and the determination of the amino acid sequence and spatial arrangement in proteins, and (3) the correlation of properties with the derived structures. New milk proteins are being isolated and two of the previously identified milk proteins, β-casein and α-lactalbumin, have been purified sufficiently to initiate amino acid sequence studies. The finding that the genetically different forms of β-lactoglobulin differed only in the content of four amino acids, namely, aspartic acid, glycine, alanine and valine, is of particular significance in demonstrating the effect of inheritance on the composition and properties of proteins. Another recent finding of general interest was the precise correlation of the refractive index of a variety of proteins with their amino acid compositions.

The laboratory was established November 4, 1958 and is located in Philadelphia, Pennsylvania. T. L. McMeekin is Leader.

ALLERGENS IN AGRICULTURAL PRODUCTS—Allergy includes an ever-widening array of human diseases. All are manifestations of abnormal hypersensitiveness to normally harmless, usually useful commodities or other materials of the human environment. Allergens are any chemically discrete components of natural, or manufactured products that may induce allergy and thereby impair the utility of those products for producer or consumer. On the other hand, the physiological reactions of allergy exhibit extraordinary sensitivity and specificity with respect to precise identity of the inciting allergen.

Investigations of allergens in this laboratory are directed to systematic analysis and synthesis of mechanisms involved in allergic reactions and in certain relevant immunologic simulations.

To date, principal accomplishments pertain to characterization of allergens of oil-bearing seeds—cottonseed and castor bean, for example; recognition of a new class of proteins distinguished by their allergenic properties; and determination of condi-

tions required for inactivation of castor bean allergen. Collateral achievements include innovations and significant advances in quantification of methods for distinguishing and comparing allergenic activity of proteins and for analysis of certain of their component amino acids. A current major project is to identify allergens of milk and other staple foods in the diet of newborn infants.

The laboratory was established January 8, 1958 and is located in Washington, D.C. Henry Stevens is Leader.

MICROBIOLOGICAL CHEMISTRY—Objectives of the laboratory are: (1) To obtain information on the chemical transformations brought about by micro-organisms; (2) to ascertain the mechanisms by which micro-organisms obtain energy for growth; (3) to study metabolic pathways, both degradative and biosynthetic; (4) to determine the properties of cellular macromolecules and the relationship of cell structure to cell function; (5) and to correlate all this information into an understanding of the physiology and life-processes of micro-organisms.

The staff has been studying extracellular lipid formation by yeasts. In the course of this work two new compounds have been isolated—tetraacetylphytosphingosine and triacetyldihydrosphingosine. A third product, a fully acetylated trihydroxy behenic acid, is now under investigation.

In the study of metabolic pathways, a strictly oxidative pathway has been found for the breakdown of pentoses which yields the biologically important product α-ketoglutaric acid. The enzyme catalyzing the first step in this reaction sequence is a relatively non specific aldose dehydrogenase capable of oxidizing a large number of sugars.

In the work concerning sexual agglutination in yeast, an assay method has been developed which permits a quantitative study of the reaction. The laboratory has investigated the chemical basis for the reaction in *Hansenula wingei* and found that the factor responsible in one of the mating types of yeast is probably a polysaccharide, whereas the factor in the opposite mating type is probably a protein. Using an enzyme known to digest the cell walls of yeast, the staff has succeeded in solubilizing the factor with polysaccharide properties in a fully active form.

With respect to studies on the relationship of cell structure to function, particularly in the photosynthetic bacteria, it has been observed that the chromatophore structure is maintained by disulfide bonds in proteins. These disulfide bonds are important not only for structure but also in electron transport mechanisms and membrane permeability.

The laboratory was established November 22, 1957 and is located at Peoria, Illinois. Frank H. Stodola is Leader.

PLANT ENZYMES—All life has been aptly defined as a system of organized enzymes. In plants, enzymes are the catalysts which play essential roles in growth and ripening. This laboratory is concerned with the identification and characterization of the specific enzymes and substrates entering into reactions responsible for the appearance or disappearance of constituents and structures important in determining the processing quality of fruits, vegetables, and other plant commodities.

Two investigations now in progress deal with the chemistry of plant cell walls and the biochemistry of post-harvest acceleration of maturation of fruit by ethylene gas. The most recent and significant accomplishment in the former study is the solubilization and characterization of a cell wall protein of unusual and distinctive properties. Fruit maturation is being studied through the use of radioactive ethylene labeled both with tritium and with carbon-14. Ethylene present in the atmosphere surrounding avocados is metabolized by a completely unexpected and unexplored pathway which might best be called the hydrocarbon metabolism of plant issue. Toluene was found to be produced in the metabolism of tritiated ethylene, with most of the radioactivity resident in the methyl group.

Plant enzyme research thus develops basic knowledge as a foundation for advancement in the utilization of plants and plant products.

The laboratory was established April 4, 1958 and is located at Albany, California. Eugene F. Jansen is Leader.

PLANT FIBERS—The chief objective of the laboratory is to obtain basic information on the supermolecular structure of plant fibers. To this end, the work is being directed along two principal lines: (a) To analyze and interpret the nature of

the fine structure present in plant fibers with emphasis on cotton; and (b) to interpret the changes in the fine structure induced by various chemical modifications of cellulose such as introduction of bulky or sterically-hindered ester or ether groups, amine complexing agents, and swelling compounds. Since the previous investigations under (a) already have been quite extensive, major efforts thus far have been applied to (b) above.

Present studies include: Structure of cotton fibers at various stages of boll development under controlled growing conditions of temperature, light intensity, period and quality, and humidity; preparation of native cellulose crystallites in the laboratory; a study of crystallite size of cellulose in its native structure; and selected modifications of cellulose structure by introduction of specially tailored chemical groups into the cellulose molecule.

Some of the recent accomplishments have included a rather full study and interpretation of the effect on cellulose fiber structure of heterogeneous reaction with cyanoethyl and acetyl groups; the preparation for the first time of a dozen or more new cellulose esters and ethers with retention of the fiber structure and partial evaluation of several of them by physical and chemical methods. Some of the esters are almost completely resistant to alkali splitting. Three new infrared absorption bands, not previously used, were found to be related to the crystallinity of the polymorphic forms of celluloses I and II. They differed in this respect to the previous measure of "crystallinity index" which was valid only for cellulose I. The modifications of cellulose structure with amines have been investigated along two principal lines: (a) A better characterization of the various amine complexes; and (b) the residual reactivity of the amine with amine-reactive substances.

The laboratory was established November 29, 1957 and is located in New Orleans, Louisiana. Carl M. Conrad is Chief.

SEED PROTEIN—Research is conducted in two major areas—proteins and protein metabolism in seeds, and biologically active proteins.

Methods have been developed for analyzing total soluble seed proteins by chromatography on DEAE cellulose; α-conarachin from peanuts was prepared by scaling up this procedure. Although pure by chromatographic standards, this protein still contains 15 percent impurity when studied by zone electrophoresis on polyacrylamide gel. Accordingly equipment is being designed for purification of seed proteins and other highly interacting proteins by preparative electrophoresis on this gel.

The laboratory has established that the majority of proteins in seeds such as the peanut exist in fragile subcellular structures. These have been isolated by a nonaqueous technique and have been observed by electron microscopy. Moreover, it has been shown that much of the lipid exists in these same structures. A novel technique of tanning the protein bodies has enabled isolation of lipid-rich fractions. These inclusions have also been observed by electron microscopy of sections fixed with osmium vapors.

As a result of these efforts, more pure species of seed proteins will be available for study of their unique chemical and structural properties. The location of the major proteins in subcelluar particles is a first step in the elucidation of their origin and biological function. It seems likely that the metabolism of these proteins will be related to that of other storage materials such as carbohydrates, lipids, and phytic acid.

The laboratory was established November 27, 1957 and is located in New Orleans, Louisiana. Aaron M. Altschul is Leader.

AGRICULTURAL MARKETING SERVICE

Market Quality Research Division

POSTHARVEST PLANT PHYSIOLOGY—Scope of the work in this laboratory includes the biochemistry and physiology of senescence and aging in plant tissues. Specifically, the two areas of study are: (1) the physiological and biochemical nature of the ripening and aging hormone, ethylene, with respect to its biogenesis and mode of action, and (2) mitochondrial physiology and biochemistry with a view to establishing the detailed components of the respiratory electron transport chain, energy conservation reactions and their alterations during senescene and general aspects concerned in regulation of cellular metabolism at the subcellular, cellular, and tissue level.

In the course of studying an enzymatic system from apples, which appeared to produce ethylene, the laboratory discovered that ethylene oxide was

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also produced in this system. In subsequent studies ethylene oxide proved to be an antagonist to ethylene and an anti-ripening agent. Ethylene oxide retards ripening in a number of fruits and extends the life of some flowers. Extensive tests have not yet been made but evidence to date indicates the discovery of an anti-ripening or an anti-aging hormone.

Undoubtedly, this is an example of a scientific discovery that evolved from basic studies directed towards rather esoteric considerations. Inadvertently, information was obtained that may have widespread practical application in the preservation of fruits, vegetables, and flowers.

The laboratory was established June 7, 1961 and is located at Beltsville, Maryland. Morris Lieberman and James E. Baker are the principal investigators.

ECONOMIC RESEARCH SERVICE

Farm Production Economics Research Division

INTERFIRM INTEGRATION—This laboratory is normally referred to as the Pioneering Research Group for Interfirm Integration in Farming. The word, "Group," seems more appropriate for use with economics research. There is also a "Basic Research Group in Marketing" in the Marketing Economics Division, ERS, that was established under a different authorization.

The area of study is that part of the organizational structure of agriculture concerned with the coordination of successive stages in production and marketing. The economic mechanisms that govern working relationships between farmers and businessmen are reflected in a great variety of formal and informal arrangements. Areas of coordination between farmers and business firms are of special interest. Significant changes in vertical integration, contracting, cooperation and other ways of coordination have occurred in recent years as economic conditions have changed.

Various kinds of vertical coordination have been examined, described, and classified into more consistent categories. For example, contracting and vertical integration are viewed as distinctly different ways of coordination. Pertinent economic theory has been marshalled, elaborated, and extended to deal with some of the problems of attaining the most economical and profitable forms of coordination for particular situations. Major coordination problems have been identified for further research.

Some specific problems have been explored on a commodity basis. One example is a study of vertical coordination in the cattle feeding industry, now in progress. When it is completed, it will furnish for the first time a good picture of the interfirm relationships between commercial feedlots and ranchers, buyers, packers, chain stores, and others.

The laboratory was established January 6, 1959 and is located in Washington, D.C. Ronald L. Mighell is Leader.

FOREST SERVICE

Division of Timber Management Research

PHYSIOLOGY OF WOOD FORMATION—The longevity and massive size of forest trees present unique opportunities as well as problems for research. Because of their longevity, trees are exposed not only to the seasonal fluctuations of environment, but also to the long-term changes in environment measured over a span of years. The wood produced within a tree is not everywhere the same and very marked differences occur in different parts of a tree during the same period of growth. The extreme variability inherent in the wood of trees is further modified in numerous ways by conditions of growth.

To segregate these many contributing factors, it is necessary to determine the underlying physiological processes of wood formation. The regulating center for all wood formation is the crown of the tree, and recent evidence indicates that seasonal patterns of wood formation in the stem closely parallel the seasonal activity of the crown. For example, the sizes of the wood cells, as measured by radial diameter, appear to be regulated by hormones synthesized by the foliage, and both the temporal and spatial gradients in wood cell size that occur throughout a tree may be accounted for by hormonal gradients. Similar gradients in the thickness of the wood cell wall that occur throughout the tree appear related to the seasonal patterns of photosynthesis and net assimilation.

Future research must further clarify the relationship between the activity of the crown and wood formation and must explore the processes that con-

tribute to variations within the walls of individual wood elements. Although it is possible to isolate certain phases of cell development for study, the many processes contributing to wood formation are closely integrated and interdependent. The ultimate aim of this project is to clarify the series of events leading to these integrated processes and to develop a generalized concept of wood formation.

The laboratory was established January 25, 1962 and is located at Rhinelander, Wis. Philip R. Larson is Leader.

FOREST MENSURATION—The objective of research at this laboratory is to develop new concepts and principles of measurement, particularly as they relate to the spatial arrangement, form, volume, growth, and quality of forest trees and stands. Scope of the work covers four broad areas of research: (1) Theories and techniques for measuring trees and stands, (2) development of concepts embodying these measurements that account for differences in growth and yield, (3) development of more realistic stand structure and analysis systems, and (4) other mathematical concepts or techniques useful in quantifying or regulating forest behavior.

Major achievements to date include an evaluation of the various types of optical instruments adapted to measuring the upper stems of trees. A new and exact mathematical basis for one of the most promising of these instruments was developed, along with a high-speed computer program exploiting the new theory. Additionally, a new and very efficient design for selecting sample trees for measurement by dendrometer was devised; the probability of selection is proportional to ocular prediction. This new technique—called "3P" sampling—has also been implemented by a comprehensive high-speed computer program.

The laboratory was established February 2, 1961 and is located in Berkeley, Calif. Lewis R. Grosenbaugh is Leader.

Division of Forest Products & Engineering Research

LIGNIN CHEMISTRY—The goal of this laboratory will be to determine the basic chemical structure of lignin, its chemical reactions, and the nature of its association with other wood constituents. Research should lead to more extensive and higher value uses for lignin, a plentiful and natural constituent of wood. The work will consist primarily of three general types of research: (1) Chemical degradation of lignin; (2) comparison of lignin with model compounds; and (3) lignin-carbohydrate association.

Although this laboratory has just been established, an increased rate of progress in this field is anticipated. The leader, in past years, has made major contributions to the fundamental chemistry of lignin. His methods of isolating lignin and comparing its reactions with known model compounds have led to important new concepts about the chemistry of this abundant and mysterious natural product. Fundamental work by the staff is expected to suggest new methods for the delignification of wood. The isolated products may have different and unusual properties of possible commercial value and application.

The laboratory was established June 21, 1963 and is located at Madison, Wis. John C. Pew is Leader.

ANALYTICAL MECHANICS—The chief objective of this unit will be to gain a deeper understanding of the basic behavior of wood and wood-base materials subjected to either external or internal forces. Research will deal with three general areas: (1) Rheological behavior of wood-base materials, (2) interaction of stresses in orthotropic materials, and (3) elastic stability of wood.

Wood is an orthotropic structure and the design criteria available for isotropic materials cannot be used to predict the performance of wood or wood-base structural components under complex loading conditions. If wood is to continue as a major structural material, methods of mathematical analysis of the internal mechanics of wood and wood-base materials under stress must be established.

Like the Lignin Chemistry Pioneering Research Unit, this one has just been established and projects are barely under way. It is expected, however, that the fundamental information to come from this unit may contribute to significant breakthroughs in the processing of woodbase materials and their use in complex structural components.

The unit was established June 21, 1963 and is located at the Forest Products Laboratory, Madison, Wis. Charles B. Norris is Research Engineer.

A Pattern of Practical Technical Assistance:

The Rockefeller Foundation's Mexican Agricultural Program

Ralph W. Richardson, Jr.

The current focus on international problems of insufficient food for populations expanding at alarming rates and the complexities in overcoming these problems can obtain a fresh perspective and draw on effective patterns of attack through a study of Mexican agricultural progress during the past two decades.

In particular, a cooperative effort between The Rockefeller Foundation and the Mexican Government which has been operative during these 20 years has developed and demonstrated concepts and techniques in international assistance which have applicability on a broader scale and can help to resolve some of the very urgent problems facing mankind today.

An invitation extended to The Rockefeller Foundation by the Government of Mexico to participate in a cooperative agricultural research venture was implemented in 1943 with the establishment of the program and assignment of one Foundation scientist to Mexico. This program grew to a maximum Foundation field staff of 18 in 1958. More than 100 Mexican scientists were then directly associated in program research projects from a total of over 500 who had received in-service training up to that time. As local competence and leadership develops, the Foundation's direct participation is being reduced; a staff of 12 Foundation personnel is working in Mexico at present.

During these 20 years of sustained research effort,

attention has been concentrated on improvement of the basic foods of that nation. Initially corn and wheat projects were undertaken in an attempt to alleviate the considerable annual deficiencies in these cereals basic to the Mexican diet. As the program developed, projects were added on soil fertility, bean improvement, plant pathology, entomology, potatoes, vegetables, sorghum, forage legumes and grasses, agricultural information, agricultural economics, and soybeans.

Conducted from the beginning as a truly cooperative program, both Mexican and Foundation scientists have worked in harmony in a team approach to all projects. In 1956 research work was initiated with livestock. From a modest beginning in that year and based upon previous years of experience in forage crops improvement, the animal science program today includes projects in improvement of poultry, dairy and beef cattle, and swine. A similar team approach to the improvement of livestock production includes management, nutrition, and animal pathology.

Statistics Reveal Problems

Mexico is and will continue to be for some time an agricultural country. A brief review of the nation and its agriculture will give an insight into the basic role of agriculture in its economy and general development. This will also serve to identify some of the general as well as specific problems confronting further national progress.

The total area of Mexico is 760,579 square miles excluding the continental shelf, or over 486 million acres, roughly one-fourth of the continental area of the United States excluding Alaska. Arable land is estimated at 74 million acres with about 37 million under cultivation. Of these 37 million acres, about 2 million are humid and 7.4 million are irrigated. The balance—27.6 million acres of tillable land—is in regions of undependable rainfall patterns or are semi-arid. The productivity potential of these lands under the best of known world farming practices today is quite limited. Mexico has approximately 250 million acres of grasslands which support a large animal livestock population of about 40 million head. Forest area is approximately 86 million acres.

The climate of Mexico, which varies from low-altitude humid tropics and desert regions to high-elevation arid plateaus and temperate zones, depends to a considerable degree on the altitude. High mountain ranges creating isolated valleys and arid plateaus above 5,000 feet in elevation are reflected in extensive temperate zone agriculture; at least 23 million acres of it is marginal crop land and vast arid rangelands. In fact, little more than one half of all arable land is planted to crops each year; the balance is left in fallow primarily because of inadequate moisture or uncertain rainfall patterns.

Mexico's land reform and land tenure systems bear significantly on current agricultural progress. Land reform in Mexico dates from 1915 and resulted directly from the Revolution of 1910. The recognition of the social function of private property is firmly established in the Constitution. Since 1915, over one hundred million acres have been distributed to landless citizens. Greatest activity in effective implementation of land redistribution did not occur until the administration of Lázaro Cárdenas (1935–1940) when over 44 million acres were distributed. Establishment of the Agrarian Code of 1934 and the institution of the National Bank of Ejidal Credit (Banco Nacional de Credito Ejidal)[1], together with this massive program of land distribution during his administration, gave the agrarian reform a new spirit and meaning as well as additional legal strength. However, the idealistic approach to land reform without adequate technical backstopping, insufficient education opportunities, lack of adequate title to the land, and insufficient credit and equipment considerably weakened the effectiveness of this national effort.

The only other brief period in history in which a comparable area of land has been distributed is the present administration of Adolfo López Mateos. During the past five years, nearly 30 million acres of land have been granted. Together with this renewed impetus on land distribution, an integrated land reform scheme has been developed. A

[1] This bank services exclusively the *ejidos*, which are communities made up of *ejiditarios*, individuals who have received grants of land from the Government under the agrarian reform program.

clearer understanding is emerging of the need for thorough technical planning and continued support associated with land distribution. A concerted effort is being made to provide substantially increased and improved rural education, increased agricultural credit, effective crop insurance, extensive price support for principal commodities, and meaningful, timely communication with the farmers of new technology to increase their productivity. These, however, are problems which have, relatively speaking, near-term solutions requiring increased dedication and effort, additional funds, and improved organization. The more complex problems of inadequate land title, alarming population increase, and the limitations imposed by a finite arable land area urgently require further study.

Ejiditarios are entitled to the land received as long as they work it. They do not, however, have full title nor can they sell or mortgage the land although they can bequeath it to their dependents. At this date, nearly 2 million ejiditarios are working lands assigned to them through definitive titles. It is estimated that these ejiditarios and their families number slightly over 10 million; they depend upon over 100 million acres of crop and grazing land for their food and income. They and their families represent over one-fourth of the population and operate over 40 percent of all crop land.

The average total area per ejido family of five persons is about 50 acres, of which only 13 acres are tillable. The production of about 6 acres is required to sustain the family itself. It has been argued that the amount of land assigned to individual families on ejidos is too small in many cases to permit them to earn a reasonable living. Add to this the facts that nearly half of all arable land is currently left fallow each year because of insufficient rainfall and that production of additional minor areas is lost for various crop failure reasons, and a tragic picture of ejidal farming emerges. Nevertheless, the validity of arguments against small land holdings is being investigated, together with a thorough re-evaluation of the productive capacity of arable lands and carrying capacity of grazing lands. Diverse soils, climate, cropping systems, and market conditions defy a generalized solution to equitable land distribution. General statements and policy which do not consider the complexities of these conditions only serve to confuse the issue and detract from agricultural progress.

The maximum area which a private farmer, as compared with an ejiditario, may own without danger of expropriation is, with certain exceptions, about 250 acres of humid or irrigated land, or 500 acres of unirrigated land, or enough to sustain 500 animal units.

Three Farming Regions

Crop lands of Mexico are roughly divisible into three major geographic-climatic regions. The central high plateau country is characterized principally by temperate zone agriculture, irregular rainfall pattern, prevalence of traditional farming practices, and highest population indices per land unit. Corn production has been basic in this region with little or no crop rotation practiced. Other important crops in the region on either area or value basis include beans, wheat, barley, alfalfa, chile, tomatoes, onions, potatoes, and strawberries. This is not typical one-crop agriculture, but crop rotation

has not been a part of the traditional agricultural production pattern. Most crop lands have been under cultivation for hundreds of years. However, during recent years, increased diversification, crop rotation, increasing use of fertilizers, expanding irrigation facilities, introduction of improved varieties and farming practices have all contributed to significant improvement in agricultural production.

The northern irrigated regions, principally the western and eastern coastal areas characterized by slight rainfall, low density of population, and high temperatures have been greatly expanded as a result of large-scale Federal irrigation projects. During the past 13 years, over 3 million acres have been brought under productive cultivation through these continuing Federal irrigation projects. Two major crops are wheat and cotton. Winter vegetables, sorghums, sugar cane, corn, sesame, safflower, and soybeans enter into the production pattern in a growing effort to diversify and strengthen the region's agricultural economy. However, these irrigated regions still produce most of Mexico's cotton and more than half of the nation's wheat crop, calculated for 1963 at 1,800,000 metric tons. These relatively new agricultural lands are highly mechanized, and technologies applied and yields obtained are quite similar to those in southwestern agricultural regions in the United States.

The tropical south and southeastern areas of Mexico are largely underdeveloped. The agricultural potential of these lands may be considerable both from the standpoint of total national productivity and as a means of gainfully employing the steadily increasing national population. These regions have received special study and development during the current administration in an attempt to expand national food supplies and produce additional export commodities including sugarcane, bananas, coffee, cacao, and henequen.

The dangers inherent in large-scale production of and economic reliance on export crops have been recognized in Mexico, and some progress has been made to diversify the crops of this region to provide greater long-term economic stability of the area.

Three fairly well defined regions of livestock production have developed in Mexico. The northern semi-arid rangelands with a particular orientation toward export of live animals to the United States suffered considerable loss during the hoof and mouth disease outbreak in Mexico. Livestock shipments to the United States were completely suspended from 1947 until 1951. In 1962 over 765,000 head of cattle were exported to the United States, together with 28,000 metric tons of beef. The 1963 cattle population is estimated at over 25 million head, compared with 14.8 million in 1950 during the hoof and mouth disease epidemic. Significant progress has been made in reestablishing this industry. One of the major factors determining the export orientation of this northern livestock production pattern, principally grass fed steers, has been the previous lack of adequate communications with the densely populated central region of Mexico and lack of adequate slaughter, feeding, and marketing facilities. The present administration has placed considerable emphasis on correction of these deficiencies, not only to improve the national consumption of beef but also to enable the nation to export a processed product of higher value in place of live animals.

The southeastern and eastern low-land tropical region is a major producer of cattle consumed in Mexico. This region has great unexploited potential in the livestock industry which is now expanding as a result of grassland management research.

The central region of Mexico is one of great diversity in livestock production including major dairy herds totaling nearly 1 million head in 1960 producing about 2.5 billion liters of milk. It is also the area of greatest concentration of the egg and broiler industry. Over 3 billion eggs and over 7 million broilers were produced in 1962 in a rapidly expanding national poultry industry. The majority of swine of the national population of more than 11 million head are also produced in this central region.

Research Brought Increases

Substantial increases in national corn production in recent years have corrected the previous deficit, and played a key role in the expanded poultry and swine programs. Research results from the Foundation's cooperative program with corn have made possible the diversion of increasing amounts of this crop as feed grain. Research has also assisted in increasing sorghum production from 51,000 metric tons in 1957 to 236,000 tons in 1962. The rapidly growing feed manufacturing industry

has largely developed with increased poultry production.

Over 12 million head of goats and more than 6 million head of sheep graze in the central and northern regions of Mexico.

The population of Mexico according to the census of June 1960 was 34,923,129. This represents an increase of approximately 35 percent since 1950 and 78 percent since 1940. A continuing high birth rate and a substantial decline in mortality rates, principally among infants, account for the average annual rate of population growth of 3.1 percent for 1950–60 compared with 2.8 percent for 1940–50. During 1961 and 1962, the annual rate of population growth was estimated at 3.3 percent,

as compared with estimated annual growth rates in the United States of 1.7 percent and 1.6 percent for each of the same years. The current population estimate is over 37 million inhabitants, thus making Mexico the most populous of all Spanish-speaking nations in the world.

The census of 1950 showed rural population to be 58 percent. During the 1950–60 decade, this percentage decreased to 49. Rural population is defined as inhabitants living in communities of less than 2,500 persons.

The present rate of increase of over 1 million persons per year, with approximately half of these swelling the rural areas, not only requires considerable annual increase in basic food items but also places tremendous pressures on programs to alleviate unemployment and poverty.

Mexico is now largely self-sufficient in the production of foodstuffs. Imports in 1950 of 7.9 percent compare with 3.1 percent of the total value of imports in 1960. Mexico, unlike many other developing nations, does not depend upon one or two export commodities for principal sources of foreign income. The three principal items in a diversified list of export products from Mexico in 1962 were cotton, 20.8 percent; livestock and meat, 7.0 percent (value $74,900,000); and coffee, 7.9 percent. Of lesser importance, fresh and processed foods accounted for 4.7 percent of the total value of exports in 1962. The combined total of all agricultural products was 52.3 percent of the value of total exports in 1962. While imports have exceeded exports every year since World War II with the exception of 1949, exports have increased in total value each year since 1957, and imports have remained practically unchanged since 1957.

The high degree of self-sufficiency in foodstuffs has been accomplished principally through research resulting in the development and use of improved crop varieties and methods of cultivation, increased production and use of fertilizers, and increases in the amount of land under irrigation. The fact that in 1962 54 percent of the country's total labor force was engaged in agricultural pursuits and produced only 20 percent of the country's gross national product points up clearly the continuing need for improvement in agricultural productivity.

The gross national product, based on constant 1950 prices, has shown an average annual increase of 4.8 percent over the years from 1950 through 1962 and has exceeded the average annual population increase of 3.1 percent. It is felt that this gross national product increase has had a corresponding effect on average per capita income. However, rural incomes of very large numbers of people, generally estimated at about 20 million, are so low as to eliminate them from the effective consumer market. The majority of these people live at the subsistence level and have little or no produce for sale, and thus extremely limited purchasing power to contribute to an expanding economy.

Economy Is Brighter

The paradox of a relatively bright economical condition with 20 million people at the subsistence level and a net increase of 1 million inhabitants each year presents a disturbing situation for the national authorities and to the agronomists of Mexico. As Secretary of Agriculture Julián Rodríguez Adame has so clearly pointed out, the basic problem is now one of alleviating poverty and finding means of

productive employment for the rapidly expanding population.

A synthesis of accomplishments of this cooperative agricultural program is necessarily limited in this review to mention of only several of the most significant accomplishments of the 20 year span of operations. These are accomplishments which have not only had measurable impact to date on Mexican progress but which are affecting agricultural development in other areas of the world.

As originally conceived, the program was aimed at improving the quantity and quality of the basic foods of Mexico. In a nation which produced only 3,122,000 metric tons of corn, 250,000 tons of beans, and 587,000 tons of wheat in 1945 to one in which these figures have been increased to 5,561,000, 617,000, and 1,433,000 respectively for 1962, the gross increase is dramatic. It is important to note that total population has increased from about 20 million to over 35 million inhabitants during this same span of years. The very fact that agricultural production has exceeded population growth, thus alleviating hunger and relieving to some degree the poverty of millions, speaks eloquently for the effectiveness of the agricultural research program and the substantial national effort and continuing interest and awareness of the Mexican Government in resolving agricultural problems basic to total national progress.

Average per capita consumption of these basic commodities has also increased significantly during these 20 years. In addition, consumption of other foods essential to adequate human diet such as animal proteins, vegetables, and other crops has increased considerably.

Crop breeding projects have produced more than 60 improved varieties of maize including hybrids, synthetics, and open pollinated types. The Ministry of Agriculture has plans for a maximum utilization of seed of improved varieties in 1963 of 14,775 metric tons, or sufficient to sow about 500,000 acres. Approximately 15 million acres of unirrigated corn are harvested annually in Mexico, which represents 93.7 percent of the total area planted to corn.

Improved varieties when grown under conditions of adequate rainfall or irrigation and following recommended farming practices may be expected to yield up to 3 tons per acre. In sharp contrast, corn produced on almost 7 million acres in Mexico averages about 12 bushels per acre. The considerable acreages of corn being grown annually on marginal land and in areas of unpredictable rainfall patterns presents one of the major obstacles to more rapid progress in improved production of this crop. In spite of this, however, it is considered that if all available technical knowledge were correctly applied to Mexican corn production, the total harvest could be doubled.

Considerable research emphasis is currently being placed on breeding corn varieties for unique drought and frost resistance. In 1962 three new hybrids, H–26, H–27, and H–28, were released for commercial production under natural rainfall conditions at high elevations where both drought and frost are common crop hazards. These hybrids appear very promising and represent an initial phase of research to improve corn yields in the less favorable production areas. Of other recent introductions, the white dent hybrid H–507 developed for the humid tropical regions is capable of producing up to 3 tons per acre under optimum agronomic practices. H–412 developed for the northern irrigated low-elevation regions produces over 2 tons per acre. These yields are realizable goals for the farms of the areas.

Deficits Overcome

Through the use of these and other improved varieties, proper use of fertilizers, and other recommended farming practices—all results of the cooperative research program—not only have deficits been overcome but Mexico has been able to launch special regional production improvement campaigns such as the "Plan Jalisco". This has increased production in that principal maize area by 500,000 metric tons in 1962, the fourth successful consecutive year of the campaign. This "Plan" together with others developing in Veracruz, Chiapas, Guanajuato, also favorable regions for corn production, provide a margin of total production security against crop failures in less favorable areas.

Results of the national wheat improvement project have been even more spectacular. The latest outstanding achievement in the long series which has marked improved wheat production was the introduction in 1961 of the two first semi-dwarf stem rust resistant varieties in Mexico, Pitic 62 and Penjamo 62. In the 1962–63 production season, these two varieties were grown on more than 75

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percent of the total national area cultivated to wheat. Improved yielding ability combined with maximum disease resistance are making possible yields of over 50 bushels per acre with these new wheats in some areas. National average yields in 1945 of 7½ bushels per acre have been increased to 32 bushels per acre in 1963.

Greater resistance to lodging under conditions of heavier fertilizer application with concurrently higher yields make these dwarfs exceptionally well adapted to irrigated production conditions. It is conservatively estimated now that by 1965 over 90 percent of the total wheat crop will be harvested from improved dwarf varieties.

Mexico is now producing sufficient wheat to carry over about 300,000 tons per year. However, in 1944 more wheat was imported than was grown in the country—509,000 tons imported versus 374,000 tons produced.

The development of high yielding varieties with resistance to prevalent races of the stem rust pathogen has not only resulted in this very favorable production situation, but also has significantly reduced the danger of severe loss from this disease. In the past, stem rust infections have reached regional epidemic proportions and resulted in tremendous economic loss in Mexico, as well as in the United States and Canada.

Current research is aimed at developing composite wheat varieties which will have several types of resistance to stem rust. Such varieties are mechanical mixtures of phenotypically similar but genotypically different lines for resistance to prevalent rust races. The plant breeders must constantly be prepared to modify the makeup of the composite varieties under production as rust races populations shift. Preliminary trials with these composites are promising.

For 11 consecutive years, the cooperative program has assisted in making possible an increase in national average yields. Production of over 80 percent of the wheat crop on irrigated lands, under ecologically less diverse conditions, lends a greater degree of universality to research recommendations, including fewer principal varieties and more broadly based fertilizer applications than is characteristic of other basic food crops. Not only do these conditions improve the opportunities for the application of large-scale production, but also somewhat simplify the agriculture extension task. These developments in wheat improvement point up the effectiveness of the research program and testify clearly to the degree of effective communication between farmers and researchers.

Similar substantial results have been achieved with other food crops: (1) Higher yielding bean varieties introduced with improved disease resistance; (2) productive, late blight resistant potato varieties opening up the possibility of widespread market and home garden production of this crop which has been a luxury item in the diets of most rural Mexicans; (3) the introduction of high quality, more productive vegetable varieties for both market and home garden uses; (4) development of higher yielding alfalfa varieties; (5) and introduction of other more productive forage crops. Comprehensive annual reports of both The Rockefeller Foundation Agricultural Sciences program and the Ministry of Agriculture of Mexico adequately document this progress.

Results achieved with livestock have also been significant. Broiler production is up 300 percent, egg production 250 percent. Program research projects have contributed to these increases, as they also have to management, nutritional, and disease studies with dairy and beef cattle and swine, resulting in increasing availability of meat and dairy products.

The indispensible modifications of traditional agricultural practices and successful introduction of new cultural methods associated with the use of improved seeds in many cases represent especially significant accomplishments. Cultural patterns and concepts of agriculture are changing. Technological improvement is now expected by the farmer and solicited from the Mexican scientists who have now clearly demonstrated their capabilities to the nation.

New Programs Developed

More than 700 Mexican scientists have received in-service training during the past 20 years in the various aspects of the program. As the needs appeared, agricultural extension programs have been developed and seed production facilities installed. Many of these capable young scientists have assumed major responsibilities with these organizations. More than 125 of these men and women, however, are directly involved as staff members of

Mexico's Instituto Nacional de Investigaciones Agricolas and the Instituto Nacional de Investigaciones Pecuarias (National Institute of Agricultural Research and National Institute of Livestock Research respectively). A number of these scientists are now in positions of complete responsibility for projects which in the early years of the program were headed up by Foundation staff. This growing level of competence is largely responsible for the gradual reduction of Foundation staff in Mexico and at the same time has made possible a gradual shift in emphasis of Foundation effort to the international application of research results from the Mexican program.

The Foundation's total investment over this 20-year span is summarized in the following table. The annual operating budgets expended by the Rockefeller Foundation on research projects of the program were supported over the years by approximately the same level of investment in the program by the Mexican Government.

ROCKEFELLER FOUNDATION FINANCIAL SUMMARY
PROGRAM IN AGRICULTURAL SCIENCES IN MEXICO
FROM 1943 THROUGH 1962

Operating Program Research Funds	$8, 474, 811. 50
Scholarships and Fellowships	1, 395, 008. 56
Grants (through 1963)	4, 685, 464. 00
	$14, 555, 284. 06

Through a scholarship-fellowship program of the Foundation which has operated in conjunction with the field program over these years, 150 young scientists (including agronomists, chemists, biologists, and veterinarians) have obtained advanced degrees from foreign universities. The majority of these scientists are staff members of the Instituto Nacional de Investigaciones Agricolas and the Instituto Nacional de Investigaciones Pecuarias. Others have assumed roles of responsibility in teaching, research, and extension with other institutions throughout the nation. In addition, 60 others are currently enrolled in graduate study programs under Foundation sponsorship, bringing the total to 210 awards for advanced study granted since the initiation of the cooperative agricultural program.

The great lasting benefits of any foreign assistance program are measured in the degree of competence developed nationally in the resolution of continuing needs and problems. The research projects provided the vehicle for training and the development of increased capabilities and confidence on the part of Mexican colleagues. The cooperative program, beyond its significant achievements in increasing food production and beyond the numerical listing of progress in food production, has accomplished far more lasting benefits as a result of its role as catalyst in speeding the development of agriculture through providing the opportunities and vehicle for development of capabilities of Mexican agronomists.

Concurrent with the operating research and the scholarship programs, the series of grants has assisted over the years in strengthening developing institutions, enabling outstanding scientists to broaden their understanding of agricultural activities in other parts of the world and to work with Mexican institutions.

Education Aided

Direct assistance through the program as well as grants to educational institutions in Mexico by the

Foundation has assisted in strengthening and expanding agricultural education. Support has been provided to the Escuela Nacional de Agricultura at Chapingo over the years, particularly in the establishment of the Colegio de Post-Graduados of that institution. Classes were formally inaugurated in 1959.

Support has also been provided to the Escuela Superior de Agricultura "Antonio Narro" of the University of Coahuila, to the Escuela Particular de Agricultura, Ciudad Juarez; to the Instituto Tecnologico de Estudios Superiores at Monterrey to assist in the development of the Escuela de Agricultura y Ganaderia; and to the Escuela de Agricultura y Ganaderia of the University of Sonora, Hermosillo. Also receiving Foundation support have been the Universidad Nacional Autonoma de Mexico for the Facultad de Medicina Veterinaria, and the Universidad de Veracruz, also for the Facultad de Medicina Veterinaria.

Other institutions have received grants from The Rockefeller Foundation. However, these few examples will serve to illustrate the comprehensive and complementary nature of support to education which has been provided to assist in overcoming the serious lack of trained plant and animal scientists in Mexico and to assist in promoting research in these institutions. Other interests, both public and private, have provided principal support in this effort, as well as supporting other scholarship programs for advanced study abroad.

The Foundation's investment in staff time in Mexico has only totaled approximately 250 man-years. In addition, temporary consultants and research associates have been assigned for short periods to assist in specific research projects.

Agricultural research and production and scientific competence had advanced to a level in 1960 that made possible the reorganization of Federal research organizations. The Instituto Nacional de Investigaciones Agricolas was established by Presidential decree on December 6, 1960. The cooperative program that had functioned as a direct dependency of the Ministry of Agriculture and Livestock was fused into the new Institute together with the entire experiment station system. Some Foundation staff members continue as cooperators in projects of the National Institute; others have been freed for assignment to other programs and to developing international aspects of the Foundation's Agricultural Sciences program.

One of the most recent developments in continuing to carry forward the results and patterns of operation from the national to international level has been the appropriation by the Foundation of $1 million for the establishment of the International Corn and Wheat Research Institute headquartered in Mexico. This international center was officially established in Mexico City on October 25, 1963.

During the past decade, Mexico has overcome national deficiencies of basic food crops. The cooperative agricultural program has assisted in accomplishing this goal. Impressive as this is—and it has been hailed by Mexican and international figures alike—it is still realized by these acclaimers and by the Mexican scientists that national consumption statistics as measured by self-sufficiency in basic foods do not necessarily correlate directly with adequate human diets. The clearly stated goal of Mexican agriculture today is to overcome the inadequate diet, poverty, and growing unemployment of great sectors of the rural population. The challenge is great, and it will strain the resources of the nation and its leaders. However, a degree of confidence now exists which is solidly based upon successful past accomplishments over similar imposing problems and an awareness of a growing number of outstanding capable young scientists.

The agricultural program which The Rockefeller Foundation and the Mexican Government have actively sustained over the past 20 years stands as the unique example of long-term productive cooperation of its type in the world today. Research results from this endeavor have not only contributed significantly to Mexico's progress but have effectively developed and demonstrated new patterns of action for national and international development in the world today—a world which urgently requires immediate action to alleviate widespread hunger and to develop the sound agricultural basis on which expanding, stable economies can be built and indispensable improvement in human well-being can be realized.

It is believed that this total of Foundation staff time in the program is modest in relationship to accomplishments over the 20-year period. The significant point is that continuity of effort on the part of dedicated scientists has accomplished much with conservative annual investments of manpower and funds.

Genetic Research on

Directed Evolution

Wendell H. Kyle

Successful research in biology usually begins with a question and ends with answers. The space between these points is filled with the routine and exciting things that constitute research. The search for knowledge of complex living organisms never really ends, because new answers lead to new and better questions and experiments. Also, there is the disquieting fact that every population of living organisms is continuously changing or evolving.

The Pioneering Research Laboratory In Basic Animal Genetics was established at Purdue University, Lafayette, Ind., in 1958 by the Animal Husbandry Research Division of the Agricultural Research Service, U.S. Department of Agriculture. It was initiated by a cooperative agreement between the Purdue Agricultural Experiment Station and the Division. The development of this laboratory, which cooperates closely with Purdue's Population Genetics Institute and Animal Sciences Department, provides an excellent example of effective State-Federal cooperation.

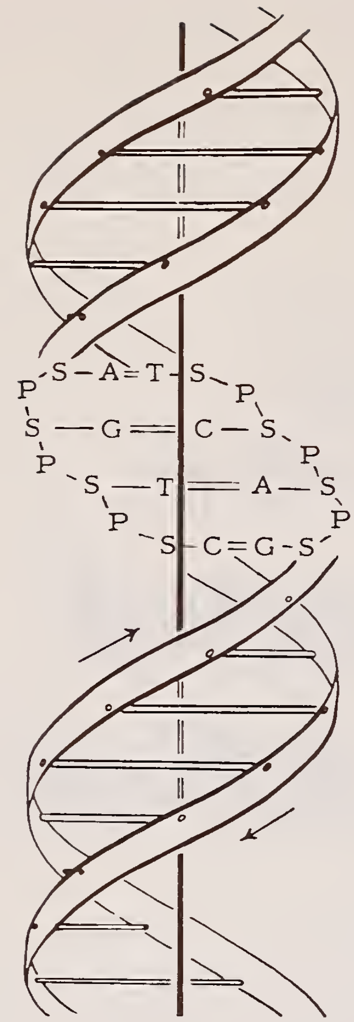
The research of this pioneering laboratory seeks answers to one primary question: "How can man most efficiently direct the evolution of finite animal populations to best serve his purposes?"

Charles Darwin and Gregor Mendel worked out the foundations of evolution and genetics approximately a century ago. However, the field of genetics was not established until the re-discovery of Mendel's paper in 1900. Also, the theory of evolution contained no satisfactory explanation for the source of variation until DeVries published the mutation theory in 1901. Significant advances occurred in 1918 and a few subsequent years when R. A. Fisher, Sewall Wright and J. B. S. Haldane provided the theoretical foundations of population genetics in mathematical terms. Experimental tests of the theory remain insufficient although a portion of the theory has been verified.

Fortunately, all pioneering research laboratories of USDA were established with complete freedom of choice regarding the research to be undertaken. In the research field for which the laboratory was founded, each investigator is free, within the limits of funds and facilities, to pursue the research problems of greatest interest to him.

Quantitative Traits Studied

In this laboratory, attention is focused on an increased understanding of the complex systems that affect and determine quantitative traits. Unlike



the qualitative traits that are determined by one pair or a few pairs of genes and appear in distinct phenotypic classes, quantitative traits have continuous phenotypic distributions and are determined by many pairs of genes. The expression of quantitative traits is almost always affected by the environment, and the effects of individual genes can seldom be identified. Therefore, statistical methods must be used to separate genetic effects from environmental effects, to estimate population parameters, and to determine the nature of gene action. Most traits of economic importance in domestic animals are quantitative traits, as are many of those which influence survival in natural populations.

In experiments on directed evolution, the researcher can control several of the factors that affect the evolution of natural populations. He can fully or partially control (a) the amount and kind of selection, (b) the kind and size of initial populations, (c) the environmental conditions, (d) the number of mated individuals per generation, (e) the mating system, and (f) the mutation rate. Time or generation interval is the greatest limiting factor because man is attempting to produce in a few generations a magnitude of change requiring perhaps hundreds of generations in nature. The only way to minimize this limitation is to use laboratory animals having short generation intervals.

Beetles and Mice Chosen

Tribolium castaneum (a flour beetle) and mice were the biological materials chosen. The beetles have a generation interval of approximately four weeks at optimum temperatures and are easy to culture in a dry medium. Dr. A. E. Bell of the Population Genetics Institute had shown their usefulness in population genetics research. His full cooperation has made possible a series of investigations with *Tribolium.* This rapidly reproducing organism is merely used as a tool for establishing the principles of directed evolution and for testing new concepts. In fact, for these purposes, laboratory animals are peerless. The *Tribolium* research has included the discovery of a trait (larval weight) showing a high degree of heterosis or hybrid vigor, formation of foundation populations from a worldwide collection of stocks, and investigation of the consequences of various mating systems with and without selection over a number of generations. Results of these studies indicate that some unusual mating systems may provide a key to more efficient evolution of animal populations.

Laboratory mice were chosen because they are one of the smallest and most rapidly reproducing mammals. The work began in temporary facilities following the gift from Mount Hope Farm of the mice and research records from two classical selection experiments of Dr. H. D. Goodale. Dr. Goodale initiated both experiments in 1931 to determine the evolutionary limits that could be reached by the continuous application of artificial, or man-made, selection. In one experiment, selection was based on body weight at 60 days of age. Although the average body weight of the population has approximately doubled, the mice have not reached the size of rats. Data from the first 85 generations of selection (over 54,000 mice) were analyzed on a high-speed computer by Dr. S. P. Wilson, a postdoctoral research associate. His re-

sults show that the consistent increases in body weight which occurred in the early generations were followed by a long period in a steady state or plateau. Despite the presence of genetic variation, continued selection for body weight was ineffective. The reasons for the plateau and ways of overcoming it are being investigated, as are concomitant changes in other traits of the population. Such plateaus present a challenge to our knowledge of directed evolution.

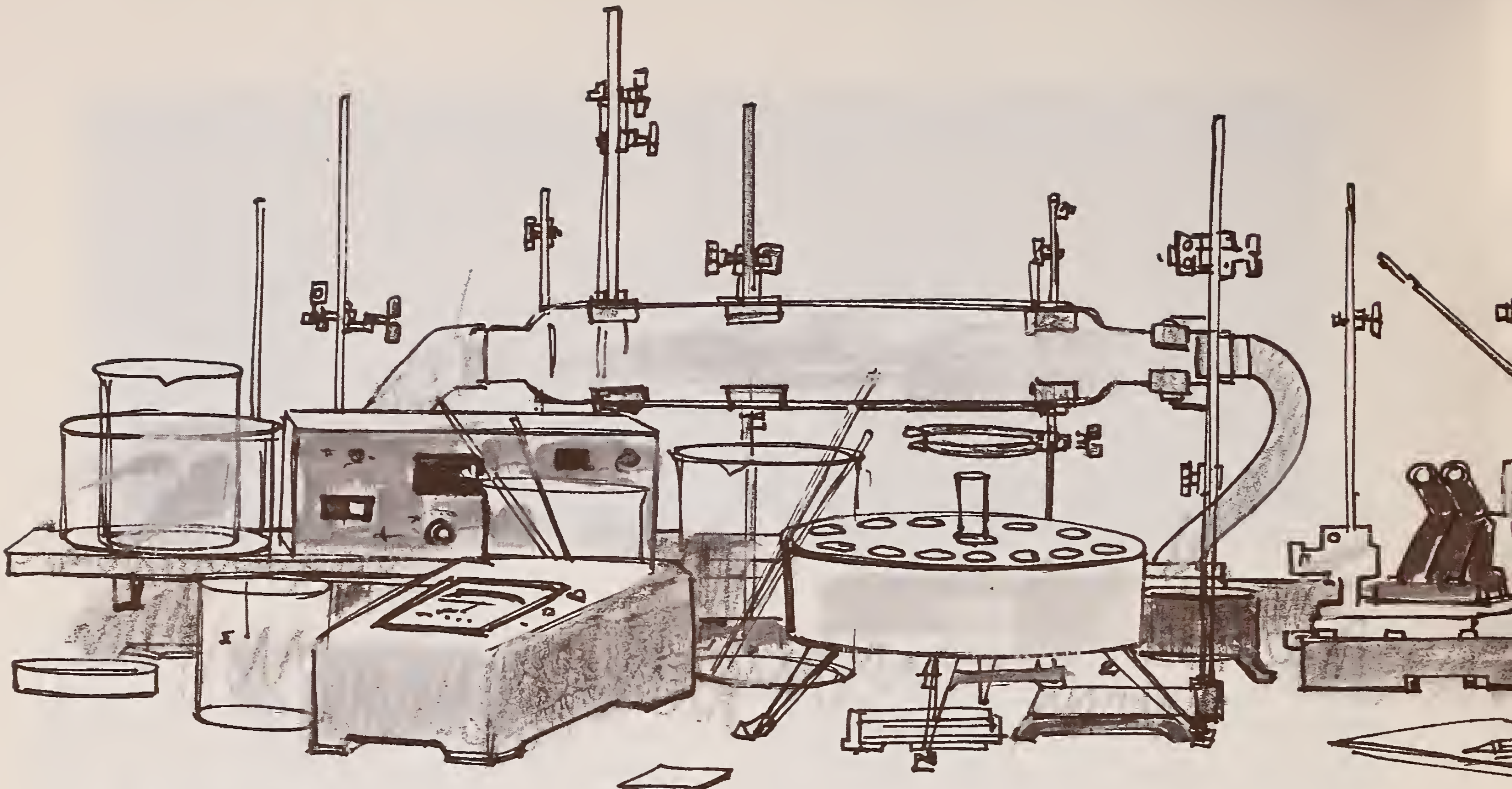
The second experiment on mice was started by Dr. Goodale from one colored male with a few white hairs on the forehead and four colored females. Selection was based on the amount of white hair. In this case, the absolute limit of evolution would be a population of all-white mice. The population is entirely dark-eyed and no albino genes are involved. The average number of white hairs and the amount of variation in the foundation population were essentially zero on the basis of present scores.

All-White Mice Increasing

Results of recent analyses were presented at the XI International Congress of Genetics in The Hague, The Netherlands. They show that the average individual score of one sub-population in this laboratory exceeds 70 percent white. The variation is large and the amount of white is still increasing at a slow rate. Thirteen all-white individuals have been obtained in recent generations. The total number of generations involved is not yet known. Whether or not the absolute limit of evolution can be reached for this trait is also unknown. It is obvious in this experiment that selection has not been a passive process in evolution, for it has extended the limits of variability far beyond that available in the original population. Although mutation cannot be entirely ruled out as a source of variation, there is evidence to support its exclusion as a major factor. The five original animals appear to have carried a tremendous amount of latent genetic variability upon which selection could act over many generations to produce an extreme change. The nature of the gene action and the number of genes are important parts of the puzzle which are being investigated.

The research on mice has been expanded and moved to new air-conditioned facilities. Differences in gene action in different environments are being studied, as are the quantitative genetics of some biochemical traits. The use of radioactive materials will be required for measurement techniques.

Future research approaches will depend to a large extent on advances in statistical genetics and on the discovery of techniques applicable to higher organisms by the field of molecular genetics. It is likely that this laboratory will direct increasing attention toward the mechanisms and measurement of gene action and interaction involving quantitative traits and toward new methods for increasing the efficiency of directed evolution. Unless and until man learns to make direct changes as desired in the genetic code or complement, the merit of his animals will depend upon efficient manipulation of the factors of evolution over generations.



Lowell W. Rasmussen

Allocating Resources in Accomplishing

Research findings of the agricultural experiment stations have contributed significantly to the dynamic nature of the agricultural sector of our country. Ironically, many of the technological changes have in turn contributed to economic and social changes that impose on us the necessity for taking a close look at future programs.

Four major factors present the experiment stations with the challenge of shifting emphasis, easing adjustments, and of keeping research work out ahead of the agricultural industry:

- Fewer people engaged in production
- Larger farm units
- Increasing inputs of capital in place of labor
- More people and capital engaged in processing, distributing, and marketing agricultural products

Another factor we must reckon with is the increased cost of doing research. Partially offsetting the tightening of public funds directly appropriated for agricultural research are the more readily available grants and contracts from industry, foundations, and other agencies. These funds, however, are often available only for specific purposes.

A thoughtful consideration of these factors poses a very pertinent question: How can we mobilize and allocate station resources to meet the challenges and accomplish worthwhile research objectives?

NATURE OF PROGRAM CHANGES

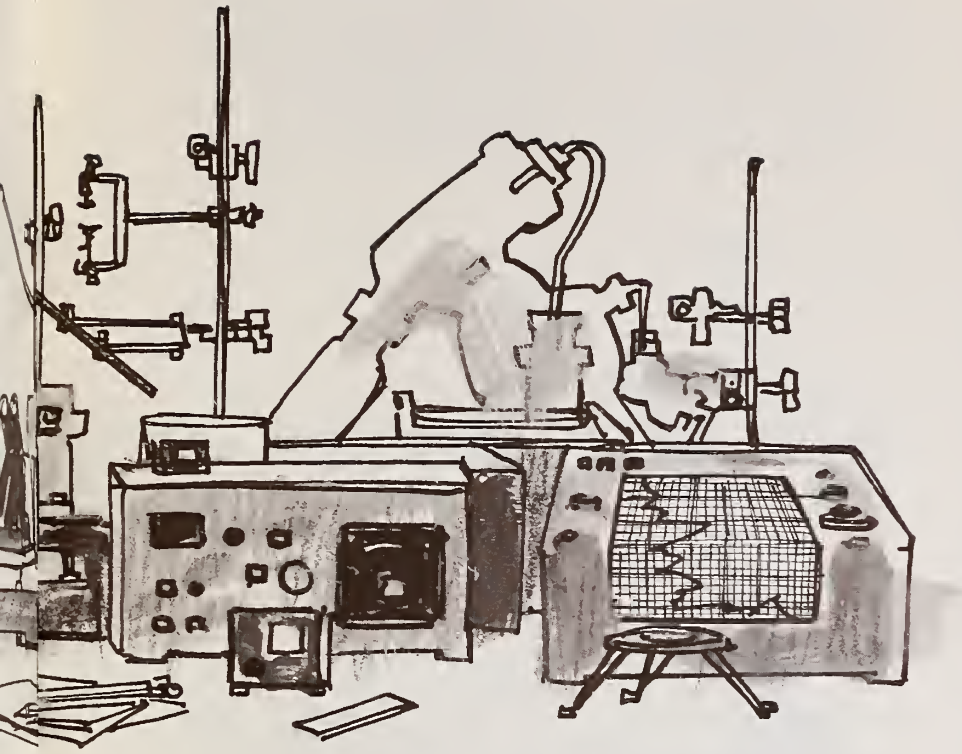
Rather than halting research as some critics have suggested, the agricultural sciences need to shift the emphasis of their research programs in several ways.

Of primary importance is the need for more basic research. Three sound reasons attest to the merit of this recommended change in programing: (a) Our storehouse of basic knowledge is running low, (b) the long-range returns for dollar expenditure are high, and (c) results of basic research generally are of greater value to the public. Ideally, most top-flight scientists prefer to do basic research.

In Dr. Alan T. Waterman's contribution to a basic research symposium [2] he stated:

"The evidence is, however, that basic research in the United States should be more strongly supported at colleges and universities, in order to strengthen

[2] Symposium of Basic Research, American Association for the Advancement of Science. Washington, D.C., 1959.



This article is adapted from a paper which the author presented at the Station Directors Workshop, Cooperative State Research Service, Washington, D.C., October 1963.

Research Objectives

our future technology by progress made on the frontiers of science, in order to retain highly competent staff, and to assure high quality training of a great number of young scientists and engineers."

At the same symposium President Eisenhower said: "The founders of the American political system clearly believed that the secrets of nature must be better known so that they might be used to advance the welfare of our people. . . . From the very outset of our Republic, the government of the United States has sought to encourage science and learning."

We need to give increased attention to solving problems and to developing basic knowledge in the economic and sociological disciplines. Problems of population shifts brought about by decreasing numbers of people engaged in agricultural production call for social science research.

A second shift in emphasis necessitated by the changes imposed on agriculture is that directed toward more cooperative endeavors, particularly regional research. I predict we will continue to have sizeable programs of the cooperative type. The agricultural experiment stations are confronted today with problems of broad regional and national scope—problems that require talents and facilities beyond the means of any one station. For example, the problems associated with proper and safe use of pesticides requires the talents of people trained in many disciplines and working under many diverse environments. Problems of food processing, distribution, and marketing call for numerous talents and on-the-spot studies in many places to obtain needed information covering the wide spectrum of marketing. Problems of international trade challenge the social and political scientists of today. We are also faced with the need for more knowledge on which to base sound, long-range uses of our natural resources—particularly our forests, watersheds, and soils. With increasing urbanization and industrialization, we must make decisions as to water-use priorities for agricultural, industrial, recreational, and domestic needs. All these demands and the problems associated therewith emphasize the necessity for much research. It is equally evident that this research is complex and requires programs involving cooperation among State stations, between State stations and governmental agencies, and, in some cases, with industry.

A third shift we should consider is de-emphasizing

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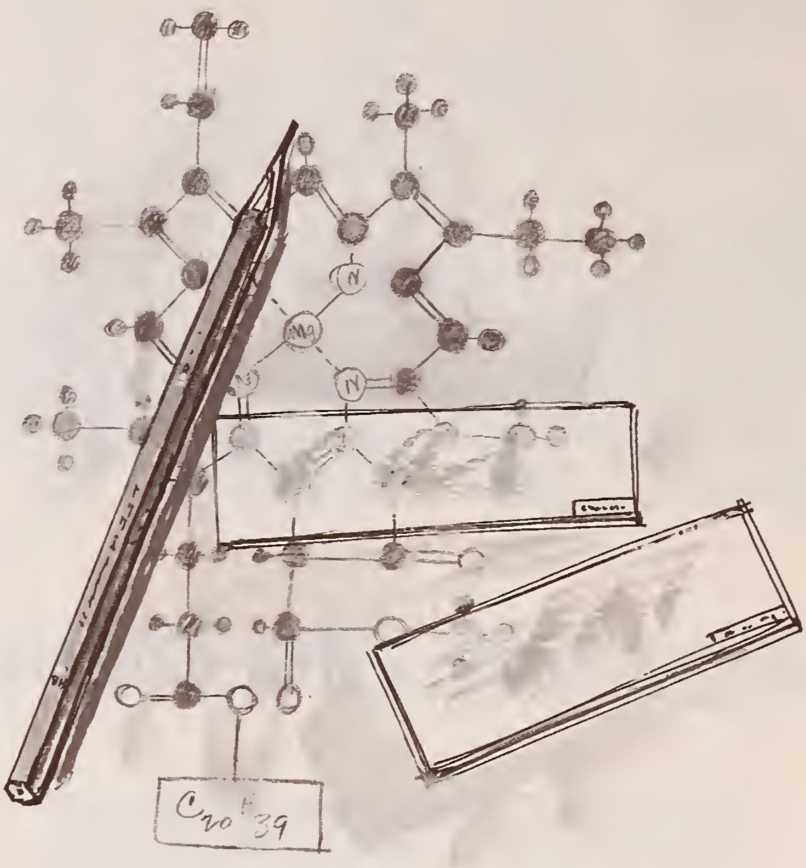
or perhaps terminating conventional lines of activity to make room for new endeavors. Because of the numerous new problems demanding research attention, I believe we have reached a time when many of the routine testing and demonstrational types of research should be greatly de-emphasized by the experiment stations. Also, service work such as answering specific problems for one or a few farmers can be reduced or turned over to private industry or the farmers' own organizations. Seed and soil testing, product analyses, production of foundation seed stocks, production of purebred animals for breeding stock, and similar activities normally performed by experiment stations have largely evolved past the research stage and into service-type operations. Some may argue that these services bring in needed money when they are performed on a fee basis. This is true. But they compete with research in the use of facilities and in the demands on the time and talent of scientists. We must protect the scientist from such work and free him for more fundamental tasks.

PROCEDURES FOR ACCOMPLISHING CHANGES AND IMPROVEMENTS

The first and most logical step in accomplishing change is to develop a picture of the road ahead. Many of our present economic and social changes have evolved gradually over a long period, and research programs sometimes have tended to resist adaptive changes that now seem to be required. We are faced, therefore, with the necessity of determining long-range objectives as a means of defining needed change and for building strong research programs. What will be the crucial problems of the future? What priorities must be established to insure the new information most likely to be required in the future? What types of scientists will we need? In what areas of research should a station attempt to build its strength?

Long-range objectives are difficult to establish, but we do have talent in the land-grant universities competent enough to study and analyze the changes taking place in the agricultural sector as well as those in industry and society. At the Washington Station we are attempting to accumulate information that will help us predict within reasonable limits the nature of agriculture and industry in our State during the next 10 to 20 years and furnish us with some idea of the possible developments in the period 1983–2000. We are attempting to determine what agricultural production will be in the various sections of the State. Along with this we will attempt to determine market outlets and how



we can expect to compete with other sections of the country in view of present and future transportation facilities. After we consider these changes and the extent to which we can expect industry to move and large urban centers to develop, we hope to be able to develop a picture of the research needs appropriate to the agricultural experiment station. We should not and cannot expect to do all things for all people. Therefore, we shall appraise our staff, our facilities, and the needs in an effort to determine in what areas we should build strength in the form of competent scientists equipped with facilities to do the desired job.

In determining what should be done not only by the station but by the individual, there is sound advice in a quotation from the late Dr. C. A. Elvehjem in a paper prepared for the World Food Forum Proceedings in 1962. He talks about the requirements and obligations of the individual scientist.

"Like all freedoms", Dr. Elvehjem said, "the freedom of an experienced and productive research

worker to be something more than a skilled employee doing the bidding of his employer carries with it a large responsibility. He must, first of all, be willing to acknowledge his basic obligation to put the public interest ahead of partisan or personal interests.

"He must be alert to new developments and new needs. When the general public becomes anxious about a problem, the demand is for action, even though there may be serious gaps in the information on which action should be based. The foresighted scientist sees a problem in his specialized area before it becomes obvious to the general public, and makes an appraisal of its potential importance. When the facts indicate the need, preliminary inexpensive studies are initiated. By the time the public becomes concerned, much essential information is already assembled, and a start has been made on exploratory studies to supply the most needed new knowledge. This ability to choose wisely the area of investigation which, all things considered, offers largest promise to a particular scientist, is one of the most valuable attributes a research worker can possess."

Although these remarks are pointed at the individual scientist, they are equally pertinent to the station which employs him.

Evaluating Programs

Program evaluation serves as a basis for identifying the nature of programs and determining the needs and opportunities for improvement. We have at our disposal a number of means, no one of which will do the job, and even in the aggregate, they may fall somewhat short. In our present day organizations, it soon becomes evident that the station director has a difficult time maintaining close personal contact with all scientists on the staff. We do have organizational structures, however, that make it possible to reach the scientists through departmental groupings presided over by an appointed head or a chairman. The departmental head must be held responsible for the research program within his department. It is up to him to determine the needs and to recommend changes of program. He must recommend the employment of appropriate staff members to accomplish the program insofar as funds and facilities will permit. It is necessary that the department head work closely with the director to give proper consideration to the long-range goals of the station.

Another means for evaluating the program is the annual report required of every scientist on each project under his leadership. If such reports are worth doing, they are certainly worth studying to determine where progress is being made and where difficulty occurred. The method I have found useful for studying these reports and the projects from which they come, is to keep a unisort card on each project. This card bears information such as title, number, leader, department, and fund source. Most of the card, however, is blank to allow for notations concerning the progress of the project. Such a notation may be no more than "satisfactory progress" or "little or no work done; check on causes." After the reports are all in, it is helpful to confer individually with each department head to review the status of the projects within his department. He in turn checks with the leader of each project in question and determines whether the project should be terminated or whether remedial action is needed to get the work under way as intended. From the reviews of the reports and the conferences with the department head, we uncover examples of noteworthy accomplishment which can be useful in preparing statements for documenting fund requests to the State Legislature or the Congress.

The newly inaugurated system of intensive reviews conducted with staff members of the Cooperative State Experiment Station Service offers an excellent method for evaluating the program. Representatives from CSESS who are competent in a particular field sit down with the scientists of a department or a discipline in which there is mutual understanding and review the projects intensively. In a recent review of this type, we allowed ample time to discuss such matters as long-range goals. We explored with individual scientists their views as to the best use of their time and talents in the future. We did this in light of our formulated ideas as to which direction we should be moving. In my opinion, this type of review is an excellent means for program evaluation.

Stimulating Productivity

The quality and quantity of a research program is influenced in large measure by the characteristics

of the scientist, the problems on which he bases his projects, and the environment in which he works. From an intellectual point of view the scientist's principal motivating forces should be: (1) The desire to know and understand some mechanism or phenomenon, (2) the desire to be able to control phenomena, and (3) the desire to be recognized by his professional colleagues as a creative scientist and productive scholar. These motivations must be safeguarded by sound administrative management and possibly by an equitable reward system. A scientist has little incentive to excel if he knows that mediocre performance receives the same reward as outstanding performance.

We must strive continually to maintain the type of working environment that will stimulate creativity. Sometimes, however, a maturing scientist begins to lose creativity. It is difficult to induce a man to change very drastically from his past research program to something new. Perhaps he suffers from lack of the right kind of motivation or because his storehouse of personal knowledge has become dated. Here, the need is for an intellectual rebirth. Through discussions such as those during the intensive reviews with CSESS, we can often point out some change of program which even the veteran scientist can adopt and thereby meet changing conditions. A leave of absence to study and work at another university or research institute may help some workers regain creativity. Others may be shifted to a team of other scientists and thereby find new challenges.

Selecting and Orienting New Scientists

In the long run our biggest opportunity for accomplishing change of program is in the selection and orientation of new scientists. In this, we need long-range goals before us to determine what type of scientist we should employ. It is desirable to examine each vacancy that occurs to determine (a) if a man of similar training to the one who left should be employed or (b) if the position should be used to initiate a new program or to strengthen an area in which we want to build competence and strength. Reviews of this type require considerable deliberation with department heads, with other administrators, and sometimes with the public. One hazard in all of these deliberations is the usual strong support for maintaining existing programs. Therefore, recommended changes must be based on sound studies and defensible long-range objectives. Along this line I should like to quote again from the paper by Dr. Elvehjem in which he states:

"The most important function of the research administrator, in my judgment, is to make sure the new people added to the staff have the competence to use wisely the freedoms and opportunities which should be the possession of project leaders in every good research laboratory. Directors of research are successful largely in terms of their ability to select and hold onto really competent scientists who continue throughout their employment to grow in their capacity to plan and to conduct research. Good research people do not need, and are not helped, by research administrators who seek to 'direct' research. Less competent scientists cannot be made first-class investigators, even when a research director tries to help them. It is rare to find today any second prizes in research, regardless of the form they might take."

Building Research Teams

Now let's consider how we build research teams for cooperative research. Basically, this amounts to finding the scientists who have professional interests in problems of interdepartmental or interdisciplinary nature. This requirement is the same whether one is building a cooperative team within the station or on an inter-station basis. Frequently there are commodity problems of major concern in a State; ours is associated with wheat. It is necessary that we bring together not only scientists interested in production phases, but also geneticists, breeders, pathologists, economists, and chemists in order to develop a balanced program aimed at major problems of long-range importance. In selecting such teams, I emphasize again the necessity of bringing together only those people who have an interest in and are challenged by the specific problems. Naturally, this kind of research must be done on a voluntary basis—voluntary, that is, in terms of the scientists visualizing the problem and formulating objectives and procedures to guide his own activities.

This same principle of the scientist's professional interest must be used in determining the degree of cooperation and participation in such efforts as regional research projects. In the past there was

some evidence that scientists occasionally got together because they visualized an opportunity to "get my share" of a given allotment of money. True, the scientist would have some interest there, but the money motivation was often very strong. In view of the recent modifications made in the handling of funds for regional research, I believe the program will be strengthened in that only those scientists will get together who have a definite interest in working on a particular problem for the challenge they see in it.

Two years ago we initiated a new venture which at the time I termed "an experiment in experimentation". This is officially designated as the CRF–1 Weed Research Program. The Congress earmarked a sum of money specifically for use in strengthening weed research. At the suggestion of the Legislative Sub-Committee of the Experiment Station Committee on Organization and Policy, the Committee of Nine formulated a procedure for conducting research on a nationwide cooperative basis. Under this system, the Committee of Nine invited each regional association of directors to nominate two representatives competent and active in the field of weed research to be members of a panel. The Crops Research Division of Agricultural Research Service was also invited to name a representative. The nine members on this panel met with the Administrative Advisor named by the Committee of Nine to outline the research problems and to establish broad objectives as guides for the preparation of specific research proposals. These statements of the problems and the broad objectives were circulated to all stations; scientists were invited to submit appropriate research proposals. Subsequently, these proposals were reviewed by the panel and the best ones were selected and arranged in a priority order. They were then presented to the Committee of Nine and as many were funded as available funds permitted. Seven projects were activated. The project leaders were then brought together for coordinating their plans and activities. This program is demonstrating an effective way of mobilizing talent and facilities to attack problems of considerable magnitude.

Allocating Funds

Planned allocation of funds can help accomplish desirable objectives. With the many different funds available, some funds, naturally, have limitations while others may be used very much at the discretion of the director. A few years ago we decided at the Washington Station to use our Hatch fund allotments, insofar as possible, to support significant basic research. Currently we do not submit a project for approval for Hatch funding unless we feel it is reasonably basic in nature. As the more highly applied and routine types reach termination or time for revision, we discontinue them as Hatch projects. This is one means whereby we can begin to move our program in the direction of basic research. We feel also that we can justify the use of some of our State funds for the support of basic research. A recent study undertaken by our Department of Rural Sociology concerning the attitude of public leaders in our State suggests strongly that a shift towards basic research would be acceptable.

Occasionally we receive from Federal and from State sources appropriated funds earmarked for specific purposes. Such earmarking does call for a shift in program—unfortunately not always in the direction that we might choose—but it does require that we maintain a certain degree of mobility in staff and facilities to meet such specified assignments.

We have been able to reorient activities and in most cases increase specific activities by the use of grant funds from farm commodity organizations. In our State, farmers can organize commodity commissions such as the Wheat Commission, Potato Commission, and others which make possible the collection of assessments for conducting business of interest to the commodity group. When this business includes support of research for product improvement, we have been able to obtain funds to increase the work of scientists already on our staff who are interested in the particular problems of concern to the commodity group. Occasionally we have gone so far as to employ people specifically to work on a problem for which the commodity commission would put up the funds. Usually the problem calls for applied research, although it may not be so restricted. There are some real plus values to such use of funds in building a program. One is a much keener interest on the part of the commodity group members to a total program. More-

over, there is a greater willingness to adopt the findings because they feel the work is theirs.

The job facing the experiment stations demands that we keep abreast of changing agriculture and establish equitable, long-range programs to meet future research needs. When this is done, the next step is to evaluate the present program, motivate shifts in it, and select and develop the human resources necessary for achieving the goals.

* * *

Research Approaches in the Social Sciences

Both common sense and scientific experience have verified that it is possible to develop methods of controlling observations, of abstracting adequately, and of reducing variability and complexity so that the social sciences can become more scientific. The social sciences have borrowed a great deal from the other sciences. More importantly than borrowing research models, they have borrowed the underlying thought-ways of science. This increasing emphasis upon research methods is, then, a sign of healthy development within the young science of human behavior.

Social scientists now see their field as having the same foundation as any other science. In this respect, two sets of forces are operating here—(a) the growing vigor within the social science field, and (b) the almost snow-balling demand upon the social sciences to provide answers to innumerable contemporary and emerging social problems.

Early research was concerned primarily with determining the social structural forms, their interrelationships, and their functions in our society. These efforts opened the way to taking the next step—analyzing the processes that take place within these social forms. Everyone of us is at once and always a part of these social systems. One is never in isolation. This of course, poses a problem for the researcher: he is at once a part and not a part of the phenomena he is studying.

With the development of studies of social processes, we began to understand better how families and individuals adopt new production, marketing, and consumption practices; how communication takes place; how migration patterns develop; how organizations develop and operate and rise and fall.

Much of this research is still two dimensional. It does a fair job of answering the "how's" and the "what's". Consideration of the third dimension of "why" certain processes occur has only recently begun.

To provide "why" answers involves getting at the attitudes, goals, values, and the whole complex of economic and noneconomic variables and factors that enter into the decision-making process, which in turn often results in some type of action. To study this most interesting and basic area of work necessitates the talents of the sociologist, psychologist, economist, and often the anthropologist. This may involve the survey, participant-observation, experimental or case study techniques, to name several, or it may involve a combination of any two or more. It may be intensive or it may be extensive. It is in this general direction that social scientists are moving. It is here where they hope to get some answers that are vexing administrators, educators, counsellors, action programers.

Change continues to be instrumental in keeping our rural society out of balance with the rest of society. But lack of balance in itself is not a unique or undersirable characteristic. Forces that create unbalance are constantly at work in any societal sector in a progressing and developing society. In the social sciences, as in other disciplines, we have had to satisfy an increasingly literate, exacting, demanding, vocal and mobile population, which has continued to demand to be better fed, better clothed, better housed, healthier, better organized, and better leisured. Neither scientist nor administrator has to argue for something to do. Our big concern will be that of constantly improving and updating our research methods and techniques to meet these increasingly changing and emerging challenges.

Paul J. Jehlik
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This article is adapted from a paper which the author presented at the Station Directors Workshop, Cooperative State Research Service, Washington, D.C., October, 1963.

A Socio-Cultural Approach to Rural Health and Rehabilitation

Victor A. Christopherson

Rx Because of the remarkable development of medical science, human beings are now able to survive conditions that would have been fatal a relatively short time ago. In contrast, the development of paramedical procedures and social engineering to help the disabled lead productive and rewarding lives has been relatively slow and unimpressive. Rehabilitation is a comparatively new field and, in general, it is as yet inadequate to meet the existing needs both on the local and national levels. Rehabilitation at its best provides for the medical restoration, reorientation, and retraining, when necessary, of handicapped and disabled individuals so that they might meet life successfully and productively in accord with their maximum potentials.

How can these new developments affect the welfare of the rural family? Does the solution of health-related problems and rehabilitation issues demand different approaches than those normally considered for nonrural families? What are the responsibilities of rural sociologists insofar as research goals are concerned? This paper [1] cannot hope to discuss and answer all these questions adequately because of the broad scope suggested by their context. Rather, an attempt will be made to shed some new light on certain phases of the rehabilitation of physically-handicapped rural people and to point out areas needing greater emphasis by the medical and behavioral sciences.

DIMENSIONS OF THE PROBLEM

With regard to the over-all need, facilities are spotty; services are largely uncoordinated and unnecessarily duplicated; and there is a widespread lack of the social machinery to bring together those in need and those who provide the skills, facilities, and services in rehabilitation. Jones (*6*) [2] gives us some idea of the urgency of the problem in his discussion of organizing medical research programs to meet the health needs of Americans. "Disease and disability are estimated to cost the United States some $35 billion per year. This economic waste would be a sufficient spur to accelerated action even if humanitarian considerations were laid aside."

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[1] Agricultural Experiment Station, The University of Arizona, No. 828.

[2] Italic numbers in parentheses refer to Literature Cited, p. 35.

The Farm Accident Picture

Even though the annual cost of disease and disability in the United States is in the billiions, Rush (*14*) reminds us that the economic cost of farm accidents is unknown. Rush states:

". . . . it is believed that hospitalization and medical treatment account for less than a fourth of the total cost. As yet, little is known about the economic loss of wages or production, which probably accounts for a considerable part of the total cost. According to a generally accepted rule of thumb, the indirect costs of industrial accidents are about four times the direct costs."

The agricultural worker, broadly defined, is of special significance inasmuch as he is statistically very prominent in injury and mortality tables. Yet his vocational disposition, once a disabling injury has occurred, is something of a mystery. For example, in Arizona many of those who receive vocational rehabilitation are referred from the State Industrial Commission. However, those eligible for Industrial Commission benefits are limited to the individuals whose injuries were incurred through the operation of farm machinery only. Very few, if any, records are kept on the large numbers who apparently do not come to the attention of the Industrial Commission or the Vocational Rehabilitation Agency.

With regard to the prior point, the farm environment and the agricultural industry appear to be among the most hazardous occupational settings. The actual number of deaths resulting from farm work has been larger in recent years than that in any other major industry; however, the death rate per 100,000 workers places the agricultural industry behind mining and construction work respectively (*10*). Rush (*14*), reporting on farm accidents in the United States, indicates that even though the farm accident fatalities run high, the non-fatal injuries sustained in farm work appear to occur about 500 times as frequently.

One of the highest estimates of disabling injuries per year sustained by agricultural workers is given by the National Safety Council. This estimate suggests that approximately 1,000,000 such injuries occur each year (*10*). The farm tractor has frequently been cast in the role of the "heavy". This villain of the farm is estimated to be involved in approximately 45,000 non-fatal accidents per year

(*11*). Gadalla (*5*), however, comes to the defense of the tractor, and suggests that perhaps more important in farm accidents are the characteristics of the people who live on farms and also, the characteristics of the farm itself. Gadalla also indicates the significance of seasonal variations in farm accidents. Winter work was found to be significantly less hazardous than that in the spring and summer.

Lack of Accurate Data

The lack of a uniform method of reporting farm accidents is also something of a problem. Undoubtedly, many accidents are not reported; thus the statistics, unless projected, are likely to be min-

imal. Inaccuracies occur from other sources as well. For example, errors might occur with regard to the age and sex composition of those reported as sustaining injuries. Gadalla (*5*) draws attention to these sources of possible error by citing a typical incident in which a child sustains injuries and is debited with the accident in the registries, even though the parent had the accident and was clearly at fault.

Rush (*14*) also calls attention to the lack of a satisfactory or standardized means of reporting farm accidents. Hopefully, procedures will be worked out in the not-too-distant future that will insure accuracy in rural accident reporting. Additional research of the kind reported by Gadalla would be very helpful in clarifying the cause-and-effect relationships of the many factors associated with farm accidents.

In order to plan for the rehabilitative needs of the injured farm worker, some means of logging his experience following disabling injury needs to be established. To what extent, for example, does the disabled farm worker remain on the farm doing the same general type work as he did before the disability? How frequently does he remain on the farm but utilize his skills in lighter phases of farm work? To what extent does he migrate to the cities seeking different kinds of work altogether? How frequently does he show up on the rolls of some type of public welfare when his remaining work potential is still sufficient to enable him to occupy a productive occupational role—assuming, of course, that retraining were available and acceptable?

Considerably more organized information is needed with regard to the farm or agricultural worker's characteristics that are associated with successful vocational retraining for urban occupations. For example, Charles Orvis, Director of the Division of Vocational Rehabilitation, Tucson, Arizona, reports that the injured farm worker who remains on the farm following the onset of physical disability is frequently very resistant to occupational training that would remove him from the rural environment. On the other hand, those who have migrated prior to contact with the Vocational Rehabilitation agency seem already to have made the psychological adjustment prerequisite to vocational re-education.[3]

[3] Personal communication, June 26, 1963.

The Migrant Worker

The migrant agricultural worker is something of a special case and largely beyond the scope of this paper. It is relevant to point out, however, that even though an injury may be the catalyst in bringing about his exposure to a vocational rehabilitation program, the content of his particular culture will possibly be as "disabling" to him as the injury itself with regard to future successful participation in the labor market. His rehabilitation program may have to anticipate and cope with a transiently oriented pattern of life.

Characterization of the Rural Culture

In seeking effective solutions to rehabilitation problems of disabled farmworkers, one cannot overlook the possible differences that exist between rural and nonrural cultural characteristics and values. Are they real, and if so, how significant are they?

In many respects, the so-called "rural way of life" has changed so that the gap between rural and urban culture has narrowed substantially. Isolated surveys in this area reveal that many farmers themselves believe their way of life is no different from that of urban people.

Other researchers, Mott and Roemer as cited by Loomis and Beegle (*7*), for example, characterize the farmer in terms that set him apart.

"The demands of an agricultural existence tend to give the farmer a psychological make-up quite different from that of the city resident. Typically, his contacts with people tend to be fewer and he is thrown more completely on his own resources . . . He is more attached to the traditional, the "tried and true" way of doing things. His closeness to nature and his relative helplessness against the ravages of drought or flood or windstorm make him somewhat fatalistic and, at the same time, rather stoical about the misfortunes of life. Obviously these attitudes have a bearing on the farm family's reaction to illness, injuries, or impairments, and to the need for medical services."

Loomis and Beegle (*7*) also call attention to the relative paucity of medical services in the rural areas. "In few services are rural as compared with urban people more underprivileged than in the medical services. Since the turn of the century, there have been progressively fewer and older doc-

tors in rural areas, whereas the opposite applies to the urban sections."

The same authors (*7*) also point out the rather commonplace situation wherein the physicians in rural areas are the senior members of their profession. Their age is 50 years or over, and most of them have graduated 25 years earlier. The significance of this matter is largely related to the recency with which rehabilitation has become a specialized field involving medicine—principally physical medicine, a specialty in its own right—and the paramedical fields associated with the useful team approach to rehabilitation; that is, physical therapy, psychometrics, rehabilitation nursing, occupational therapy, psychology, vocational counseling and home economics—principally nutrition and work simplification.

TRENDS IN SOCIO-CULTURAL RESEARCH

An approach to health problems that appears to have much promise, and which, fortunately, seems to be increasing, is the inclusion of behavioral science departments in medical schools. Representative institutions that have recognized the need for teamwork of the kind made possible by combining these disciplines, are Stanford University, Yale University, the University of Kentucky, the University of Denver, and a number of others.

Straus (*17*) cites a study conducted by Mabry entitled "Human Response to Illness" which ". . . has focused on attitudes, values, beliefs, and alternative ways of dealing with health problems among samples of the population of two rural and one urban counties." Other studies are in process and are being planned at the Medical Center at the University of Kentucky which will ". . . consider the significance of psychosocial and cultural factors in programs of patient care."

When socio-cultural data are considered along with medical factors, a more complete and useful approach to health problems is provided. More information is needed concerning the rural worker's attitudes toward health-related matters and toward certain kinds of occupational alternatives. Illustrative of the socio-cultural approach is a study by Zborowski (*19*) of the pain reactions of several ethno-cultural groups.

Zborowski's findings indicated that some patients tended to provoke worry and concern in their social environment as to the state of their health and the symptomatic character of their pain. They were concerned with the long-range implications of their conditions. Another group tended to provoke sympathy toward their suffering, and a third group differed from both the others in being more detached, stoical, and less emotional about the pain.

Somewhat similar was a study by Sanua (*15*) of the behavior of several ethnic groups of aged persons in terms of their reactions to amputation.

Studies of these kinds dealing with rural groups stratified along such lines as socio-economic status, size of farm enterprise, region, and ethnic identity would yield valuable information. Such studies would further our understanding of the significance and role of socio-cultural factors in human physiology and responses to injury.

Frank (*4*) believes there is occurring a kind of revival of the Hippocratic concept of man and disease. Some of the ecological assumptions of Hippocrates are perhaps a little naive by present-day standards. But the transformation, as Frank puts it, of such vague concerns as the danger of night air, the miasmas, and the whole gamut of folk medicine into carefully controlled investigations of modern epidemiology, and areal studies of incidence and severity, and the ever increasing number and variety of environmental factors now recognized as significant components in the understanding of disease—all attest to the importance of the present-day expression of the Hippocratic view. Demographic and ecological studies of a health-related nature conducted in a selected variety of rural communities, when carefully compiled, would be of great value in planning rehabilitation procedures and rural health facilities.

More information is needed relating specifically to the rural family and to the significance and role of the family when one of its members becomes disabled by accident or disease. Studies and information of the kind provided by Parsons (*13*), Christopherson (*1, 2*), MacFarland (*8*), and Marra and Novis (*9*) would be particularly helpful in this regard were they to deal specifically with the rural community.

Vincent (*18*) provides an excellent and critical review of family research related to health. He believes that there have occurred a number of errors and over-simplifications in characterizations of the American family which have been perpetuated in

the literature. Educators, researchers, and counselors in the marriage and family field have taken too literally the ideal-type model of the small, isolated, nuclear family, Vincent states. The hypothesis that sick-care functions are incompatible with the organization of the modern family and the notion that sick, aged, or incapacitated persons endanger family cohesion may only be applicable to such an ideal-type model. Vincent further contends that failure to examine the reciprocal influences or transactions between individual illness and the total family is not simply a failure by default. It represents, at least in part, a blind spot fostered by some theoretical and methodologic shortcomings in family theory.

The socio-cultural approach to the study of factors that frustrate or facilitate the rehabilitation of disabled individuals in an agricultural or rural environment would appear to have considerable promise. However, progress in a comprehensive and interdisciplinary approach to the problem will be a long-range and possibly up-hill matter. Cottrell and Sheldon (*3*) point out one source of difficulty that members of the "team" have frequently experienced in working together—a difficulty that arises from cultural bias. They write:

"In the health field . . . the medical practitioner is trained to see his problems in terms of the individual organism or segments of it; the social scientist conceptualizes his problems in terms of interaction among organisms. If the medical man thinks of the environment, it is primarily the physical environment that he considers important. Attempts of the social scientist to analyze the processes of social interaction, the development of roles and their systematic relations in institutional patterns, and the relating of these facts to illness and health, are likely to strike the medical man as lacking in reality and relevance. While the social scientist perceives the physician as deplorably narrow and naive about the dynamics of human relations, his own innocence of biological sophistication makes him appear to the latter as unsound and of doubtful competence."

The several kinds of problems of collaboration discussed by Cottrell and Sheldon should not, in any sense, be considered a justification for disregarding the contributions of any of the professions that attempt to work toward the solution of rehabilitation or other health-related problems. An ever increasing tendency toward interdisciplinary cooperation in medical schools, universities, and community health programs attests to the soundness of the approach. Preventing disabling accidents and diseases and, once they have occurred, helping the individual acquit himself with dignity and profit both occupationally and socially are goals worthy of the best talents of all members and potential members of the team. That agricultural injuries result in a tremendous economic and human loss cannot be gainsaid. It is time that both medical and behavioral sciences accord the rehabilitation of the injured farm worker the high priority the problem deserves.

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The New International Plant Index

Nearly 2,000 copies of the first volume of the "International Plant Index" are already in the hands of the taxonomic botanists of the world. Titled, *Family Names of the Plant Kingdom,* IPIx–1, the book has been described by William C. Steere, director, New York Botanical Gardens, as "the first step in a monumental project that will eventually see all the names of all plants of the world listed in an orderly manner, together with author, date, and place of publication."

One of the primary purposes of the project is to achieve both rapid recording and rapid retrieval of botanical information. Naturally, this will permit botanists to spend less time searching the literature and more time for actual research study in the field and laboratory. IPIx–1 was prepared by the use of punched cards and data-processing machines.

National Science Foundation supplied the grant-in-aid funds for the project. The two cosponsors are New York Botanical Gardens and Connecticut Agricultural Experiment Station.

The book has been particularly well received by workers in those areas of the plant kingdom that have no consistent indexes. These include every discipline except the flowering plants. A large majority of the flowering plant taxonomists seem to be generally favorable to the work, according to letters we received from many of them. A small group of the conservatives of the profession, however, took exception to the work.

At present, work is being concentrated on the genera of the plant kingdom. We now have on punched cards 20,000 of what we term "operative" generic names; that is, names in active use that are being prepared for publication. In the search for errors we have already printed the list twice—each time in less than 2 hours.

I believe this is the first time in botanical history that the genera of all parts of the kingdom have been brought together in one alphabetical listing. This work has brought to attention nearly 500 exact homonyms, most of which are still outstanding. This is only the beginning. But it makes clear that there are perhaps thousands of species in an uncertain position due to homonymy. A great deal of taxonomic work will be required to repair this situation. Our view is that the work should be undertaken now, and a concerted attack be made on the problem.

Taxa citations require the names of the authors and the publications within which the names were first published. Thus, we have recorded the names, birth and death dates, and the countries worked in of some 7,500 authors who named plants, either individually or in collaboration. We have about 5,000 publications associated with those authors. Both of these listings are almost ready for publication. They represent a body of material that should be of great value to many workers.

We have been asked many times as to when the Index to the entire kingdom will be finished. If we are granted funds to proceed, we estimate that about 10 people working for perhaps 5 years might have most of the IPIx in print. It will amount to about 2 million names and require 50 volumes to complete the work. Thereafter, the work can be maintained by a very small group of people.

Sydney W. Gould,
Director, International Plant Index.

The Role of Tenure in Agricultural Science

Effective application of modern science and technology in the less developed areas of the world requires that cultivators of the land be free men and citizens, operating land which they own or hold securely, and owning at least an equitable share of the product of the land. These are essentially the avowed objectives of land reform programs all over the world.

The path to the realization of such objectives for any country depends, quite naturally, on the circumstances from which development starts. At least three major kinds of situations need to be distinguished: (a) There are large areas in the less developed regions in which the predominant tenure forms are those which have developed by custom and tradition out of the primitive struggle for survival. This is true in much of Africa and in parts of Asia and Latin America. (b) The more general situation where agriculture has partially been oriented to a market economy is one of depressing economic and political inequality. These power-oriented problems and inadequacies are the major roots of the current land reform problem. (c) Cutting across both types of tenure problems in some of the less developed areas are urgent problems of overpopulation.

Although a dense population in agriculture and the resultant small holdings of land are not in themselves tenure problems, amenable to tenure reforms, the density of population may limit appreciably the kind of tenure alternatives open to a country undertaking reconstruction and development.

The application of science and technology in alleviating population pressure on the land is mediated, as in other circumstances, through the economic organization and tenure system. Nevertheless, the possibilities of modern science and technology are uniquely relevant to the areas of overpopulation. This follows from the fact that overpopulation is a condition of man's numbers outrunning his control over physical nature. Stated differently, as a matter of policy (in the absence of a calamitous decrease in population) the ratio of people to available physical opportunities can be reduced only by increasing such opportunities. Since changes in such ratios cannot be achieved rapidly in any economic system, the natural zone of freedom open to cultivators crowded onto tiny plots is necessarily restricted. Even in such circumstances the land and labor are almost surely to be more productive if the land is held by the cultivators on terms which assure them secure occupancy and the benefits of intensified production effort. But even under the most liberal tenure arrangements, a cultivator of a tiny tract of land cannot enjoy extensive freedom; the physical basis of freedom is lacking.

It is inconceivable that science and technology, which can be developed creatively only in communities enjoying freedom of thought, can be exploited fully in agriculture except in a tenure system which accords to people a role of dignified freedom in the daily conduct of farming.

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Adapted from a United Nations Conference paper, Geneva, Switzerland, February 1963.

Microclimate and Physiology of Citrus: Their Relation to Cold Protection

William C. Cooper,
Roger H. Young,
and Franklin M. Turrell

In December 1962 the Florida citrus industry was devastated by the most damaging freeze in 70 years. Approximately 15 million of the State's 52 million trees were killed and 50 million boxes of fruit were lost. Another 50 million boxes of fruit were damaged but salvaged as concentrate. Substantial wood and foliage damage occurred in approximately ⅔ of the citrus-producing areas of Florida, including the major citrus-producing counties of Lake, Orange, and Polk. Physical tree damage and losses from this 2-night freeze amounted to nearly $500 million. The loss of income for the next several years will be several times the loss from initial tree damage.

In proportion to the sizes of the industries, freeze losses to citrus grown in the Lower Rio Grande Valley of Texas during the past 15 years were even more catastrophic than those in Florida. Each of 3 major freezes (January 29–31, 1949; January 29 to February 3, 1951; and January 9 to 13, 1962) killed or severely damaged most of the bearing trees in the Valley.

In California severe freezes occurred in 3 successive winter seasons: 1947–48, 1948–49, and 1949–50. In January 1963 the temperature dropped as low as 20° F. in the Tulare County area for 8 consecutive nights. The principal damage was to fruit; tree damage was generally limited to 1- and 2-year-old trees.

On the average, major freezes with temperatures of 20° F. or lower occur about every 10 years in Florida, Texas, and California. Minor freezes with temperatures of 25 to 29° F. over fairly large areas occur 10 to 25 nights a year in California, about once

every 2 years in Florida, and about once every 3 years in Texas.

This, therefore, is the problem: How can we best provide maximum cold protection to the Nation's multi-million dollar citrus crop? It is a problem that concerns engineers, meteorologists, and plant breeders alike. Where physical methods of cold protection are neither feasible nor available, the use of cold-hardy varieties is the most logical approach. The combination of cold-hardy varieties and physical methods, where feasible, provides maximum protection from cold damage. Regardless of the approach, much information is still lacking, particularly in the physiological and phenological aspects of citrus. This paper summarizes present knowledge gained from studies of these areas in relation to protection of citrus from cold and discusses the best long-range approach to solving the problem.

MICROCLIMATE OF THE TREE

An understanding of the microclimate of the tree (temperatures of the air, leaf, twig, fruit, bark of trunk, and soil) is important in explaining the heat exchange between the tree and the environment. Leaves act as a medium of heat transfer between the sun and the earth during the day and between the sky and the earth during the night. Radiant energy reaching the upper surface of a horizontal leaf in full sunlight on a clear day is the sum of direct and scattered sunlight plus the downward stream of infrared radiation from the atmosphere. The canopy of the tree cuts off most of this radiation to the inside leaves, but these leaves do receive thermal radiation emitted by the leaves of the canopy and thermal radiation from the ground surface. The leaf exchanges its radiant heat load by reradiation, convection, and the energy used in transpiration.

Turrell showed that at times lemon leaves exposed to the sun may reach temperatures 10 to 15° higher than those of the ambient air. In 1962 tests, the author found that the daytime temperatures of Valencia orange leaves varied greatly, depending upon whether the leaf was exposed to full sun, partial sun, or no sun.[1] For 2 years, temperatures of Valencia orange leaves were recorded every 32 minutes at Orlando, Fla., Weslaco, Tex., and Indio, Calif. The mean daytime temperature of leaves exposed to the sky on the south side of the tree was substantially higher at all seasons of the year than that of the ambient air. Daytime temperatures of shaded leaves on the south side of the tree and of leaves exposed to the sky on the north side of the tree were similar to temperature of the ambient air at most seasons.

Nighttime heat exchange of lemon leaves was determined in the orchard and under laboratory conditions (Turrell, Austin, and Perry, *22*).[2] The heat absorbed in vaporizing the water transpired was very small in warm air and almost negligible in cold. Radiation and convection fractions were approximately equal in both warm and cold air. In warm air accompanied by a strong wind, as compared with warm still air, lowered transpiration

[1] W. C. Cooper, 1962. Unpublished data.

[2] Italic numbers in parentheses refer to "Literature Cited," p. 50.

resulted from tighter closure of the stomata. The convection fraction of heat was greatly increased and radiation was unchanged.

In an orchard under natural conditions, radiative cooling of leaves exposed to a cold sky occurs whether the wind is strong or light. But the leaves are not cooled markedly below air temperatures unless the winds are so light that sensible heat transfer to the leaf from twigs and ground inside the canopy of the tree is less than that lost by radiation to the sky. In a lemon orchard on a clear, cold, calm night, exposed leaves cool by radiation to a temperature one to several degrees lower than the ambient air (Turrell, Austin, and Perry, *21*).

Radiative cooling of leaves markedly below the air temperature occurred on Valencia orange trees in orchards in Florida, Texas, and California in the winter of 1961–62 (Cooper, Peynado, and Furr, *4*). In each instance the radiative cooling of leaves below the air temperature occurred on a cold, calm night with inversion layers in which the air temperature at a 40-foot height was 5° or more higher than the air temperature at a 6-foot height.

Practically all freezes and a large proportion of local frosts follow the passage of a cold front and subsequent influx of polar air. Each cold front carries with it its own particular type of weather. Sometimes cold, calm air follows the influx of polar air without any local indications of the passage of a cold front. However, during the major freezes in Florida and Texas, strong, dry winds accompanied low night temperatures for one or more nights, followed by one or more nights of cold, calm air.

Temperature and wind conditions during the January 9–13, 1962 freeze at Weslaco, Tex. characterized the combination advective and still-air freeze. During the first two nights, wind velocities of 8 knots accompanied minimum air temperatures of 23.5° F. Leaf and air temperatures were the same, and there were no vertical temperature inversions (Peynado and Cooper, *15*). On the third night, the wind subsided, vertical temperature inversions developed, and exposed leaves cooled markedly below the air temperature.

Fruit exposed to the sun during the day and to the cold sky at night absorb the sun's radiant heat during the day and lose radiant heat to the sky at night. Fruit temperatures reflect this radiant exchange of heat just as do temperatures of leaves.

Twig temperatures are nearly always the same as the air temperature in the tree canopy and show the same diurnal variations. During the Texas freeze of January 9–13, 1962, twig temperatures closely followed the same pattern as the air temperatures. The temperature of the trunk cambiums, however, did not drop to the same minimums as air temperature. The minimum air temperatures on the 3 freeze nights were 23.5, 24.5, and 12° F. as compared with 26, 27, and 21° F. minimum temperature for the cambial area of the trunk. There was also a distinct temperature lag in the soil under the tree; the minimum at the 6-inch level during the 3 freeze nights was 48.7° F.

Temperatures of the ambient air of a citrus tree, then, do not adequately describe the entire microclimate of the tree. Leaf temperatures fluctuate more widely from day to night than do air temperatures; twig temperatures fluctuate about the same as the air; trunk temperatures much less than the air; and root (soil) temperatures considerably less than the air.

Air temperature, however, is a good parameter for describing the variation in the climatic properties of the grove environment at any location. Table 1 illustrates the variations in the seasonal climate of 7 citrus-growing regions. Air temperatures in the fall and winter are substantially higher at locations in Florida and Texas than in Arizona and California. During the winter, soil temperatures at the Florida and Texas locations were approximately the same as the mean day air temperature (approximately 65° F.); those at the Arizona and California locations were near the mean night air temperature (approximately 45° F.).

DORMANCY OR ARRESTED DEVELOPMENT

In the development of citrus, seedlings pass through a juvenile stage marked by the absences of flowers, greater vigor of growth, and other morphological features, including leaf form, growth habit, and thorniness. The growth vigor of young seedlings is so great that under favorable environmental conditions growth is often continuous. Intermittent growth interrupted by periods of no visible outward activity characterizes the growth pattern of budded old-line citrus trees.

In the citrus-growing regions of South Africa and Israel, where seasonal fluctuations in temperature are small and the winter temperature is mild,

there are commonly 4 flushes of shoot growth, followed by periods of growth interruptions. These growth flushes occur in early spring, early summer, early fall, and early winter.

In the citrus-growing regions of the United States, where the winter climate is generally cold, mature bearing Valencia orange trees generally have 3 flushes of growth occurring in early spring, early summer, and late summer or early fall. Winter night temperatures usually fall below 55° F.—the minimum temperature for growth of oranges. There is no flush of shoot growth during this season, and all buds usually remain quiescent from late fall until early spring. If, however, unseasonably warm air temperatures occur in December, as in Texas in 1948, a fourth flush of growth occurs. Not all buds on a tree produce new shoots at each flush of growth.

The spring, summer, and fall periods of growth interruption of shoots of mature, bearing citrus trees generally occur under environmental conditions which are favorable for growth. Thus, the growth interruption at these periods does not appear to be caused by any environmental condition. The flush of growth on a particular twig is usually

TABLE 1.—MEAN AIR TEMPERATURES[1] IN CITRUS GROVES DURING DAY AND NIGHT AT 7 STATIONS DURING DIFFERENT SEASONS IN 1961

Season and observation period	Orlando, Fla.	Clermont, Fla.	Weslaco, Tex.	Tempe, Ariz.	Indio, Calif.	Riverside, Calif.	Santa Paula, Calif.
	°F.	°F.	°F.	°F.	°F.	°F.	°F
Early spring (Feb., Mar.):							
Day	74	73	78	62	69	59	59
Night	60	61	66	49	55	44	42
Late spring (Apr., May):							
Day	79	77	83	78	79	71	66
Night	64	65	72	59	63	52	47
Early summer (June, July):							
Day	85	83	88	90	86	82	72
Night	74	73	77	74	80	62	56
Late summer (Aug., Sept.):							
Day	85	82	87	87	90	79	72
Night	75	73	76	71	76	62	58
Fall (Oct., Nov.):							
Day	77	74	77	67	73	64	66
Night	64	64	65	52	55	48	49
Winter (Dec., Jan.):							
Day	66	65	63	55	56	59	62
Night	55	56	54	43	49	44	47
Annual mean:							
Day	79	76	79	73	76	69	66
Night	65	65	68	58	63	52	50

[1] Means of hourly readings throughout day or night. The day includes the daylight period from sunrise to sunset; night includes the dark period from sunset to sunrise.

limited to one or two of the terminal buds; the growth of lateral buds is inhibited by the terminal bud. As leaves are produced by the new shoot, the terminal growing point is in turn inhibited by the new leaves. In citrus, this inhibition is so strong that it causes the terminal growing point to die and dry up; extension growth of the shoot ceases. Doorenbos (*7*) referred to this type of growth interruption as summer dormancy. The term "bud inhibition" seems more appropriate and will be referred to as such in this review.

It is now well known from the early work of Thimann and Skoog that auxin produced in the terminal growing bud of a plant is of crucial importance in the inhibition of lateral buds. Cooper (*2*) has found that the young leaves of new actively growing citrus shoots produce copious quantities of auxin. If, however, the leaves are removed from the shoot, one or more buds near the terminal end of the new shoot will resume growth. It, therefore, appears that auxin is involved in the inhibition of lateral buds on citrus shoots; this bud inhibition is released as soon as the auxin supply to the buds is cut off by defoliation.

In recent years numerous workers found that two other groups of naturally occurring growth regulators—gibberellins and kinins—cooperate with auxin in the control of bud growth. Wickman and Thimann (*24*) showed that inhibition of the growth of lateral buds of the pea plant by apical dominance is due to an interaction between auxin, kinin, and gibberellin. Cooper and Peynado (*3*) showed that gibberellin applied to mature, bearing Red Blush grapefruit trees during the summer released buds from inhibition in a manner similar to defoliation. It is not known exactly what is involved, but the results suggest that gibberellin acts in some way to deplete inhibitory concentrations of auxin in the new shoots.

If there is ample soil moisture during these periods of bud-inhibition of citrus in the spring, summer, and fall, cambial activity in the twigs, branches, trunk, and roots continues uninterruptedly. Reed and MacDougal (*16*) have reported that the growth of the cambium of young citrus trees is cyclic; periods of intermittent cambial growth alternate with cycles of growth of shoots. Schneider (*18*) and Cooper et al. (*5*) have not found this to be true for mature, bearing Valencia orange trees. In fact, cambial activity of 20-year-old Valencia orange trees is almost continuous except when growth inactivity is imposed by drought, heat, or cold. This drought- heat- or cold-imposed growth interruption disappears as soon as the environment again becomes favorable for growth.

Usually drought interrupts the growth of buds and roots as well as the cambium. In the case of cold, the plant tissues and organs affected depend on the microclimate of the tree during the cold period. Usually during the winter season in California, the ambient air temperature falls below 40° F. every night and soil temperatures range be-

tween 40 and 50° F. The temperature of the roots, trunk, and outer canopy of the tree falls below the minimum temperature for growth (50° F.); and buds, cambium, and roots of the entire tree cease growth. On the other hand, in Florida and Texas during the winter season, the ambient air temperatures at night usually do not fall much below 50° F. and soil temperatures are usually 10 to 15° higher. Under these conditions there is no growth activity in buds and of the cambium in twigs, but there is cambial activity in large limbs, trunks, and roots as these tissues may have a temperature near 65° F.—well above the minimum temperature for growth.

In this review growth inactivity in either buds, roots, or cambium that is imposed by drought, cold, or heat and is released when temperatures and soil moisture become favorable for growth, is referred to as dormancy. Bud dormancy in citrus depends on environmental conditions unfavorable for growth; bud inhibition does not. There is no evidence for a chilling requirement for breaking either condition, but both conditions are broken by appropriate gibberellin application.

The cold-imposed bud dormant condition in the early winter is usually preceded by the bud-inhibition condition following the early fall flush of growth. Thus the bud inhibition and dormant conditions overlap and it is difficult to establish just when dormancy begins. During the bud-inhibition period in the fall, the shoots undergo a maturing or aging process in which soluble sugars are lessened, starch increases, cell walls thicken, and the shoot becomes more rigid and less succulent (Jones and Steinacker, *11*). As winter dormancy sets in, shoots accumulate sugars with no concurrent change in starch, and the shoots become more rigid. With the advent of warmer weather in February, sugars are converted to starch and buds break dormancy and begin the spring flush of growth.

The ease with which auxin, produced in growing buds, of many woody plants diffuses basipetally through the stem tissue into agar receiver blocks suggests that the excess auxin from the current shoot flows into the shoot of the previous year and for indefinite distances downward. There is also substantial evidence to assume that this auxin is responsible for the initiation of cambial activity in the twigs, branches, and trunk of the tree. The auxin action, however, may be dependent on endogenous kinins already present in the cambium. There is no substantial evidence that gibberellin has a direct effect on cambial activity. Although there has been relatively little work done on the effect of growth-regulating substances in citrus, it has been shown that the distribution of auxin in citrus is substantially the same as that described for other plants.

The first noticeable change in the cells of the cambium of citrus in the spring is a swelling; an increase in the trunk circumference results. Cambium at this stage is quite succulent and the bark slips readily. The break occurs in the cambial region and the cambial face of the bark is generally moist. Once cell division starts and new cells are differentiated, further increase in trunk circumference occurs and continues all summer and fall if environment is favorable for growth. Cambial activity in citrus slows considerably during the winter in Florida and Texas and is usually completely stopped in Arizona and California; however, it may continue in the trunk well into December.

Since the cambium may remain active in citrus during prolonged bud dormancy—provided environmental conditions are favorable for growth—it appears that the tree must have centers of auxin production other than in the growing shoot. Söding (*19*) reported evidence that the active cambium produces auxin.

Adequate root growth data are not available for precise evaluation of root growth. However, limited data by Schneider (*18*) and Cooper et al. (*5*) indicate that the periodicity of root growth and dormancy of mature bearing Valencia orange trees is similar to that of cambial activity in the trunk. Under the cold soil conditions of Arizona and California, there is no root growth in the winter.

EFFECTS OF CLIMATE AND VARIETY ON DORMANCY AND COLD HARDINESS

Development of a portable tree freezer to freeze citrus trees under controlled conditions greatly facilitated field studies on cold hardiness. By the use of a large tree freezer, Young and Peynado (*26*) studied changes in the cold-hardiness characteristics of 10-year-old Red Blush grapefruit trees during the winter of 1960–61. Warm air temperatures (65° to 70° F.) prevailed during November, cooler temperatures (45° to 60° F.) during December and January, and warmer temperatures (65° to 70° F.)

during February and March. During November shoots were dormant but barely mature and the bark was readily slipping throughout the tree. In December the shoots were fully mature and the bark was slipping; in January the bark was barely slipping on the shoots; and in February new shoots were 1 to 6 inches long and the bark was readily slipping and succulent. The trees were exposed to 23° F. for 4 hours during the 3rd week in November, December, and January and the first week in March. Leaf and twig injury was severe in November, less severe in December; slight leaf damage and no twig injury occurred in January; and severe leaf and twig injury occurred in March. Thus imposed cambial dormancy related to cool winter weather increased cold hardiness.

In another series of growth-chamber tests, grapefruit seedlings were exposed to several successive day-night temperature treatments for 2 weeks prior to a freeze treatment (Young and Peynado, *27*). As the preconditioning temperatures were gradually lowered, twig cambial activity gradually decreased and leaf cold hardiness increased. In these tests the seedlings, as a result of exposure to low temperature, tolerated 7 degrees lower temperature than the controls.

The wide variation in cold hardiness among citrus varieties and species is explained in part by the difference in the minimum temperature at which dormancy is induced. Many field observations have shown that varieties and species which develop bud dormancy earlier in the fall and remain dormant later in the spring generally exhibit more cambial dormancy and cold hardiness in the winter. This is true of trifoliate orange, citranges, citrumelos, and most mandarins. In contrast, limes and lemons, which are notoriously cold sensitive, usually grow actively during the midwinter. With controlled temperatures in a growth chamber, Young and Peynado (*27*) demonstrated that citrus types which exhibit more cambial dormancy and cold hardiness in the winter stop active growth at warmer night temperatures than do the cold-sensitive types such as limes and lemons.

The relative effectiveness of dormancy in increasing cold hardiness thus varies with the climate and

the variety. In California and Arizona low night temperatures commonly occur in the winter, but they usually come and leave gradually. Therefore, lemons, which require low temperatures for induction of dormancy, generally grow well in coastal California even though they are cold sensitive. When severe winter freezes do occur in California and Arizona, lemon trees in the interior regions are usually dormant and will withstand more cold than the same variety grown in Florida and Texas where relatively warm winter weather does not induce dormancy of lemons. On the other hand, citrus varieties that go dormant during the moderately warm winter weather characteristic of most of Florida and the citrus area of Texas are more likely to survive winter freezes in those States (Cooper et al., *5*).

In Texas tests with citrus (Young and Peynado, *26, 27*), the cold-imposed cold hardiness was associated with increased cambial dormancy of the twigs. A cold-hardening effect unrelated to dormancy was not distinguishable. It is probable, however, that a cold-hardening effect not related to dormancy does exist. According to Levitt (*12*) the series of biochemical and biophysical changes associated with cold hardiness in plants include accumulation of sugars, —SH, and —S—S— groups decrease in total water content, increase in crystalloidally bound water, increase in solutes, decrease in protoplasm consistency, and increase in protoplasmic permeability.

EFFECTS OF DROUGHT ON DORMANCY, COLD HARDINESS, AND COLD PROTECTION

Plants subjected to a reduced water supply undergo many of the same changes in development and physiology as during preconditioning to cold. Cooper, Tayloe, and Maxwell (*6*) demonstrated that 3-year-old Meyer lemon trees can be protected from cold by drought. Water was withheld from the trees between November 12, 1954, and February 12, 1955, during which period there was no rain and night temperatures dropped below 40° F. twelve times at widely scattered intervals. The dry trees were uninjured by exposure to 20° F. for 3 hours as determined by tree-freezer tests, and one week after irrigation the trees were injured by an exposure to 26° F. for 3 hours. In anatomical studies on grapefruit trees growing in wet and dry soil, Hussain and Cooper (*10*) showed that cambial activity was slower developing and more feeble during the winter in terminal shoots of dry trees than in the shoots of the wet ones.

Furr,[3] also, observed the beneficial effect of drought on cold hardiness of 1-year-old lemon trees at Pomona, Calif. Furr's plots were set up to study the effects of soil moisture on soil aeration. An early freeze killed all leaves of trees in the wet plots but scarcely injured those in the dry. In these experiments, the ground was covered by straw, which probably reduced the heat radiation effect of the wet soil, and the leaves of both wet and dry trees were probably subjected to about the same temperature.

Drought and cold hardiness were correlated in citrus nurseries in Texas during the 1949 freeze. Because there was a surplus of nursery stock before the freeze, several nurseries were not irrigated for several months prior to the freeze. Trees in these nurseries were uninjured; the irrigated trees in all other nurseries were killed.

The most critical work on relations of photosynthesis and transpiration to drought in tree crops is that of Loustalot (*13*) with pecans. Since there has been no comparable work on citrus, that on pecans is cited because the same general principles apply. The photosynthetic rate of pecans was hardly reduced until the soil had nearly reached the wilting point. After the trees wilted, the loss of CO_2 from respiration exceeded photosynthesis. Thus moderate drought in pecans may result in: dormancy, accumulation of sugars and other metabolites, decrease in total moisture content, and a corresponding increase in the osmotic pressure of the cell sap. However, when drought is severe and prolonged, especially if part of the dry period occurs in hot weather, sugars and other food reserves may be greatly reduced by respiration and deleterious changes in the tissues result.

Similar changes in citrus trees probably occur as a result of severe drought and may reduce cold tolerance (Turrell, Austin, and Perry, *21*).

In practical citrus growing, anything that tends to weaken trees—too little nitrogen, damage from virus and fungus diseases, excessive drought, poor

[3] J. R. Furr, 1937. Unpublished data in private communication.

drainage, previous freeze injury, and salt injury—will decrease cold hardiness. The use of drought as a cold-protection method should be tempered with caution. It probably has no practical application in California and Arizona where winters are generally cold enough to induce dormancy and cold hardiness. On the other hand, in Florida and Texas the winter climate is warmer and slight to moderate drought conditions in the fall and winter increase dormancy and cold hardiness. Irrigation promotes continued cambial growth and growth of the fruit all winter.

During the winter of 1948–49, December weather was unseasonably warm in Texas (minimum temperature for the month was 70° F.). There had been no severe freeze for 18 years and growers had come to expect warm weather every winter. Many growers gave their trees an extra irrigation in early January. The warm weather plus the favorable soil moisture conditions caused new shoot growth and abundant cambial activity in the trees by the time of the freeze of January 30. Air temperature of 19° F. for 6 hours was general throughout the citrus region. All fruit was frozen, all leaves killed, branches of 1 to 2 inches in diameter killed, and abundant bark splitting on large limbs and trunks occurred. It thus appears that moderate drought used with caution is a practical method of cold protection in Florida and Texas.

EFFECT OF IRRIGATION WATER ON COLD PROTECTION

Studies by Hilgeman and Howland (*9*) and Turrell, Austin, and Perry (*21*) have shown a protective influence of irrigation water during freezes in Arizona and California. Application of water to the irrigation furrows in a citrus grove before or during a freeze provides cold protection as a result of the large specific heat capacity of water at its initial temperature and of the release of latent heat on freezing. Also, a wet soil is a better heat conductor and results in more radiation of thermal heat to the tree during a "freeze night." Increased heat transfer from a wet soil warms the microclimate of the tree and a small amount of cold protection is thereby provided.

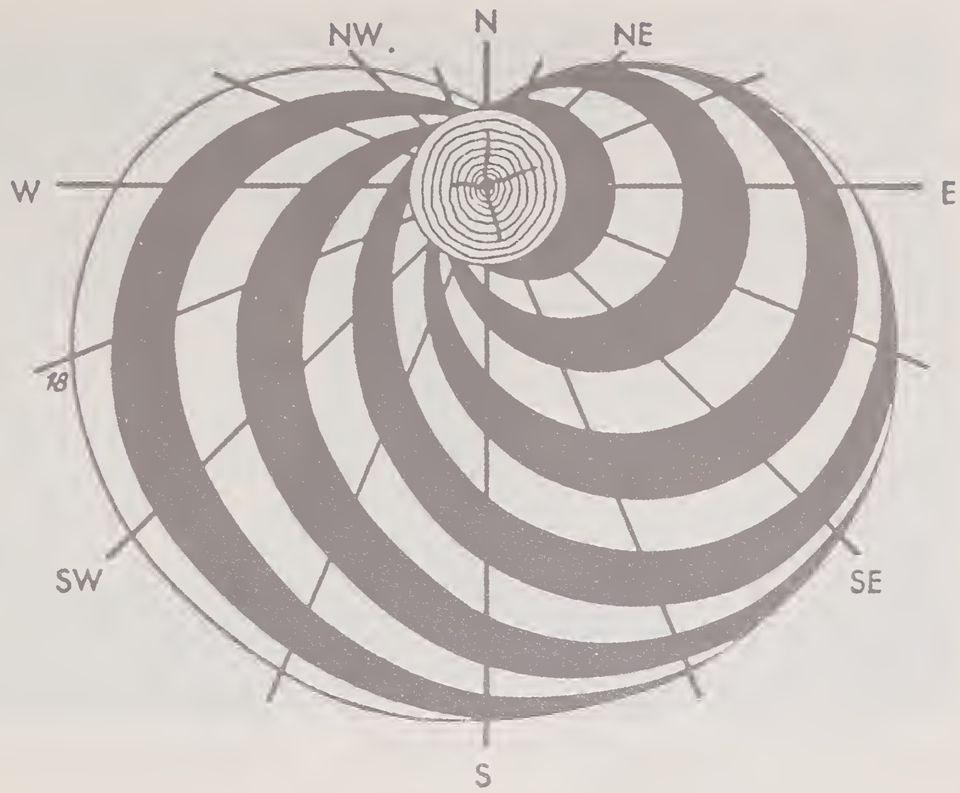
When water is applied at the time of a freeze, this physical warming effect on the microclimate of the tree is quite different from the physiological effects of increased cold hardiness of the tree induced by withholding irrigation water for a long period prior to the freeze. Under natural conditions the relative degree of freeze injury in a dry and wet orchard during a freeze will depend on whether the degrees of protection from drought-induced cold hardiness in a dry orchard are as large as the degrees of protection from a warmer microclimate in the wet orchard.

Irrigation by running water in furrows in orchards in California and Arizona on the night of a freeze is an accepted and beneficial practice. The same method could be used on the heavy soils in Texas. But applying irrigation water to dry trees under Texas conditions would result in the promotion of growth following the freeze, thereby increasing the possibility of damage from a later freeze.

In Florida, because the soil is light and sandy, irrigation water is applied by some form of sprinklers. If overhead sprinkers are used, the freezing of the water on the leaves and fruit provides latent heat which keeps the temperature of the fruit and leaves at the freezing point of water as long as more water is freezing on the outside of the ice layer (Rogers, *17*). Water applied at the rate of 0.1 inch per hour provided good freeze protection to citrus in Florida during the radiation type freezes of December 26 and 30, 1961, when minimum air temperatures were generally 23° F. or above and the air was calm and moist. However, under the conditions of the December 12–13, 1962 freeze, where air temperatures were generally 20° F. or below, the dewpoint was 6 to 12° and wind velocities of 10 knots or higher occurred, systems supplying only 0.1 inch of water per hour were generally unsuccessful in providing cold protection. Where more water was used, cold protection was accomplished, but breakage of limbs from the weight of ice became a factor.

EFFECTS OF WIND ON FREEZE DAMAGE AND COLD PROTECTION

A night wind exceeding 3 knots usually prevents inversions in temperature; radiative cooling of the leaves below air temperatures is reduced; and freeze injury may be prevented. Such occasional prevention of freeze injury by wind in California led to the development of wind machines for artificial freeze protection (Brooks et al., *1*). The



use of blower wind machines for freeze protection is a general practice in California, and their use with supplementary heaters is well established. Since the 1957–58 freeze in Florida, wind machines in low ground areas have been used extensively where air temperatures around the tree are generally 5 to 10° colder than those on high ground. Orchard heaters are occasionally used in low-ground orchards in Florida, but their use with wind machines as in California is not well established.

Where inversion temperatures of 5 to 15° F. occur naturally in citrus orchards in California and Florida, wind machines are generally beneficial because of turbulent mixing of cold air near the ground with warmer air at 30 to 40 feet, thereby transferring more of the heat in the overhead air down into the orchard. This warms the air surrounding the tree, slows the cooling of the leaves and fruit, and decreases the time that they are exposed to freezing temperatures.

Where there is no warm air inversion in temperature, wind machines prevent cooling of the fruit and leaves below air temperature by increasing sensible heat transfer from the parts of the tree and the ground inside the canopy toward the exposed fruit and leaves (Turrell et al., *23*). Under some circumstances this may be beneficial and under others it may not.

The characteristic of plant tissue to cool somewhat below its freezing point before ice begins forming in it may have practical importance in cold protection because undercooling itself does not cause freezing damage. Wind under some circumstances may lessen undercooling of citrus fruit, thereby increasing the hazard of freeze damage.

Hawkins (*8*) determined that orange fruit on trees in the orchard frequently undercooled as much as 8° F. below the freezing point of the fruit. This was confirmed by Lucas (*14*) for lemons and by Turrell, Austin, and Perry (*20*) for oranges. Young and Peynado (*25*) studied the changes in temperature of Red Blush grapefruit leaves on small plants in a walk-in-freezer cooled to 20° F. at the rate of 15° per hour. Leaf temperatures were recorded every minute until the leaves were frozen and their temperatures had equilibrated with temperature of the air. The initial drop in leaf temperature was steady and continued to 22° F., which was 3° below the freezing point of the leaves. At that temperature, water soaking of the leaves became apparent and the leaf temperature rose abruptly to 25° F., the true freezing point of the leaf. At this point the leaf was completely water-soaked. The temperature of the leaf subsequently decreased, indicating that most of the solute within the leaf was frozen and that no further heat of crystallization was being released. The undercooling period lasted longer on leaves from dormant trees than on leaves

from actively growing ones. Also, the length of the undercooling period and the freezing point of citrus varieties varied.

Turrell, Austin, and Perry (*20*) found that orange fruits may remain in an undercooled state for hours without freezing. The air temperature may be gradually increased to above the freezing point of the fruit and no ice crystals will be formed. On the other hand, if ice crystals form while the fruit is undercooled, the fruit temperature rises rapidly to the freezing point of the fruit and it is frozen.

The undercooled state is unstable and the circumstances which control passage from the undercooled to the frozen state are not fully known. Lucas (*14*) conducted a study of undercooling in lemons and concluded that wind lessens the undercooling of fruit and thereby raises the temperature at which freeze damage may be expected. The effect of wind on undercooling requires further investigation before this problem can be solved.

A fast-moving cold dry air has a very destructive effect on citrus trees. During the December 12–13, 1962 freeze in Florida, wind velocities of 16 knots persisted all night and there was a large forced convection inside the foliage cover of the trees. No difference in temperature occurred between high and low ground and between leaf, twig, fruit, and ambient air. Injured leaves appeared desiccated, or freeze-dried, and retained their green color and dry, brittle texture even after abscission. Turrell, Austin, and Perry (*22*) have shown that wind extracts heat from leaves faster than still air. In dry fast-moving air, heat loss by convection will cool leaves to a lower temperature and more quickly than in still air. It is generally accepted that freezing kills tissue by dehydration of the cell; water accumulates in the intercellular spaces and turns to ice. Leaf desiccation probably occurs after death of the tissue. The 16-knot dry wind favored such desiccation even though the stomata were probably closed.

At the time of the December, 1962 freeze there was little evidence of bark slippage (cambial activity) in twigs and small branches, but cambial activity occurred in localized areas on large limbs. Because of the large amount of forced convection resulting from the penetration of cold air inside the foliage cover of the tree, all parts of the tree were exposed to the cold and the localized areas on the large limbs, which were less dormant, developed freeze lesions while the more dormant twigs and small branches were generally uninjured. This localized the cold-damage areas to the large limbs and led to the girdling of these limbs and the collapse of the limbs several months later, after a temporary regrowth in the small branches and twigs of the tree.

DISCUSSION

Cold protection of citrus generally has been considered a heat transfer matter to be solved jointly by engineers and meteorologists. This approach has been successful in California where low temperatures are constant during winter and all varieties of citrus grown are generally very dormant and tolerate temperatures as low as 20° F. without injury. In Florida and Texas, where winter weather is not likely to be consistently cold, the same varieties are usually severely injured at that temperature. Therefore, in Florida and Texas physiological factors affecting the cold hardiness of the tree have great bearing in coping with the cold-protection problem. Cold hardiness depends on winter dormancy controlled both by the genetic systems of the plants and by such environmental factors as temperature and soil moisture. The usefulness of water in cold protection varies with the climate and the kind of freeze.

One of the most obvious methods of reducing losses from freezes is production by breeding and selecting cold-tolerant varieties. Citrus breeding began in this country in 1893 by Webber and Swingle and continued until 1930 by Swingle, Robinson, and Savage. The trifoliate orange was used as the principal source of cold tolerance. Crosses between trifoliate orange and various kinds of citrus proved to be of outstanding cold tolerance, but their fruits were practically inedible because of the disagreeable flavor that the trifoliate orange transmitted to its progeny. More recently citrus breeders have used the satsuma and Changsha mandarins as sources of cold tolerance in crosses with sweet oranges.

In testing these progeny for cold tolerance in the field under natural freezes, it is not sufficient to measure freeze damage resulting from a single freeze. A variety may show severe freeze injury following an early freeze because of a lack of dormancy. But later in the winter when the variety

is fully dormant, it may show considerable tolerance to freezes. Also, the extreme variability in freezes and prefreeze conditions is a deterrent factor in testing cold tolerance in the field. If one waits for suitable test winters with natural freezes, it may require 30 years to establish the relative cold tolerance of a new hybrid.

For most effective breeding work it is essential that we know more about the nature of cold tolerance in citrus. The breeder must know what hereditary characteristics to look for and how to make tests of seedling progenies so that reliable selections of cold-tolerant individuals can be made. It is obvious that one of the factors involved in cold tolerance of citrus is dormancy of the tree. The cold-tolerant trifoliate orange and mandarin types become dormant at temperatures around 60° F, while sweet oranges require temperatures about 5 degrees lower for a cessation of growth. Thus the trifoliate oranges and mandarins are likely to enter the dormant state earlier in the winter than are the sweet oranges and because of the earliness in dormancy are likely to be more resistant to early freezes. Also under winter conditions, where the microclimate of the trunk and large limbs at night is generally 10 or more degrees warmer than that of the ambient air temperature in the orchard, the trees of trifoliate orange and mandarin types are likely to be more fully dormant and more cold tolerant than the sweet orange types.

Another possible heritable factor that citrus may possess is the ability to undergo true cold hardening when preconditioned to low temperatures in the range of 26 to 40° F. Very little is known about the cold-hardiness factor in citrus because of the complication of the dormancy factor.

The problem of developing a suitable testing process on hybrid seedlings under controlled environment—and of accelerating the testing—is now being undertaken by physiologists. But one important unanswered question is: Where heritable differences occur between varieties cold hardened at temperatures just above their freezing point, will comparable differences occur between the same varieties when they have been preconditioned to normal winter temperatures (50° F. for Florida) that may influence only the dormancy factor? Development of reliable and satisfactory test methods will permit predictions about variety behavior in a specified climate, and thus aid the hybridizer in planning a better breeding program.

The complete recovery of citrus trees from severe freezes requires up to 5 freeze-free years (Young and Peynado, *28*). Citrus growers in Florida and Texas are now concerned with the possible damaging effects of even minor freezes on their heavily pruned citrus trees. Under these circumstances heaters, wind machines, or other physical means of cold protection may be feasible devices to insure against further tree loss.

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* * *

Passport For Progress

GREAT challenges still face our colleges and universities. One of these was brought out in "Harvard and the Federal Government—a Report to the Faculties and Governing Boards of Harvard University." The study delved into the subject of Federal grants for science and education in an age when our academic institutions are increasingly engaged in performing scientific research for the Government. "The role of the university," concludes the report, "cannot be one of withdrawal from the world. But it will serve society well only as it remains true to its essential nature—a university, not an agency of government. It is entitled to demand complete intellectual freedom. To this end it must ask for a measure of detachment from current crises and routine procedures as necessary conditions of fulfilling its fundamental purpose in civilized society."

Such thinking becomes our passport for tomorrow, not only for teaching and developing young people of our great country, but also for those who may be attracted from horizons beyond our shores. There is no better key to successful planning for the future than a good understanding of the past. Today we know that the strong interdependence between scientific research and higher education of quality is what has made the land-grant colleges great—this and adherence to the concept of academic freedom.

The challenge to all science and education in the end should be the goal of human advancement. The land-grant colleges and universities during their first 100 years have provided a remarkable example of progress toward that end. A continuing objective must be that of greater excellence in all areas of educational responsibility. The advancement of scientific knowledge and wide dissemination of its truth among our people and those of the world are the surest way to expand opportunities of the individual at home and abroad. In this direction lies our greatest assurance of a free and progressive society.

H. C. KNOBLAUCH,
Associate Administrator,
Cooperative State Research Service.

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"False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for everyone takes a salutary pleasure in proving their falseness."

CHARLES DARWIN 1809–1882

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